DGP-WG/04-IP/8
30/9/04

DANGEROUS GOODS PANEL (DGP)

MEETING OF THE WORKING GROUP OF THE WHOLE

Abu Dhabi, 4 to 8 October 2004

Agenda Item 6: Resolution, where possible, of the non-recurrent work items identified by the Commission or the panel.
6.3: Review of provisions for dangerous goods carried by passengers and crew

PASSENGER EXCEPTIONS

(Presented by by R. Richard)

INTRODUCTION

The following two reports are provided for the information of the DGP members.

a) The first report is "Fire Hazards of Aerosol Cans in Aircraft Cargo Compartments". The purpose of this project was to determine the hazards associated with aerosol cans involved in cargo fires. It was initially conducted in 1989 as a result of replacing CFCs with flammable propellants in aerosol cans. Even though the testing was completed several years ago, the results are still valid as the same conditions exist today.

b) The second report "Potential for Ignition of Flammable Aerosol Propellants by Static Electricity Inside Checked Baggage" was conducted as a result of incidents resulting in fires or explosions over the past several years involving flammable aerosols in checked baggage. The report consolidates the incidents with some general observations and considerations.

As the passenger exceptions are being reviewed for possible restructuring, this information is provided for consideration in evaluating the present exceptions. No specific proposal is being offered at this time. The information is provided strictly as information.

Based on a review of the passenger exception provided in the TI and the US Hazardous Materials Regulations a number of minor amendments are proposed to Part 8, Chapter 1 (see attached)

Exceptions for Passengers and Crew members
Recommendations for Amendments to ICAO Part 8;1

ICAO Part 8;1 (As of 19th DGP)	*Issue Noted*	*Recommendation*
a) when in retail packagings, alcoholic beverages containing more than 24 per cent but not more than 70 per cent alcohol by volume, in receptacles not exceeding 5 L, with a total net quantity per person of 5 L for such beverages;	a) To align with security measures and airline policy the DGP should revise the exception for alcoholic beverages to indicate that the alcohol be in "*unopened retail packagings*". Since passengers can't drink their own alcoholic beverages on board (e.g. 14 CFR 121.575) this amendment makes sense. TSA and other security administrations are also currently rejecting opened packagings from a security standpoint.	Revise ICAO text by adding the word unopened so that it reads as follows: a) when in **unopened** retail packagings, alcoholic beverages containing more than 24 per cent but not more than 70 per cent alcohol by volume, in receptacles not exceeding 5 L, with a total net quantity per person of 5 L for such beverages;
b) non-radioactive medicinal or toilet articles (including aerosols). Also aerosols in Division 2.2, with no subsidiary risk, for sporting or home use in checked baggage only. The total net quantity of all such articles carried by each person must not exceed 2 kg or 2 L and the net quantity of each single article must not exceed 0.5 kg or 0.5 L. The term 'medicinal or toilet articles (including aerosols)' is intended to include such items as hair sprays, perfumes, colognes and medicines con-taining alcohols;	US regulations are consistent with the requirements of the TI but the US competent authority and other competent authorities interpret "medicinal and toilet articles" differently. Flammable aerosol mosquito repellent is one example. The US does not consider this a medicinal or toilet article. Perhaps these terms should be defined. This may be an area of discussion for the working group/sub-group.	The working group should consider whether the text can be clarified to provide additional guidance on what items apply. Consideration should be given to defining medicinal and toiletry articles.
c) with the approval of the operator(s), small gaseous oxygen or air cylinders required for medical use;	In the US this is not authorized; The operator is required to supply oxygen if necessary through prior arrangement.	It is difficult to control cylinders provided by passengers. The integrity of the cylinder may be satisfactory. For instance it may not be within test date, the valves may have been changed (tapered thread valve inserted in cylinder neck with straight threads). This should be discussed by the DGP working group.

ICAO Part 8;1 (As of 19th DGP)	*Issue Noted*	*Recommendation*
d) dry ice in quantities not exceeding 2 kg per person, when used to pack perishables are not subject to these Instructions, provided the package permits the release of carbon dioxide gas: — in carry-on baggage; or — with the approval of the operator(s), in checked baggage;	The marking provides an additional safety measure that requires the passenger to undertake an additional check.	It makes sense to mark the package if it is offered as checked baggage since it will be inspected by personnel who will be unaware of the contents. Propose to amend f) to read as follows: f) dry ice in quantities not exceeding 2 kg per person, when used to pack perishables not subject to these Instructions, provided the package permits the release of carbon dioxide gas: — in carry-on baggage; or — with the approval of the operator(s), in checked baggage**, when each package is marked "DRY ICE" or "CARBON DIOXIDE, SOLID" and marked with the net weight of dry ice or an indication that the net weight is 2 kg (4.4 pounds) or less.;**

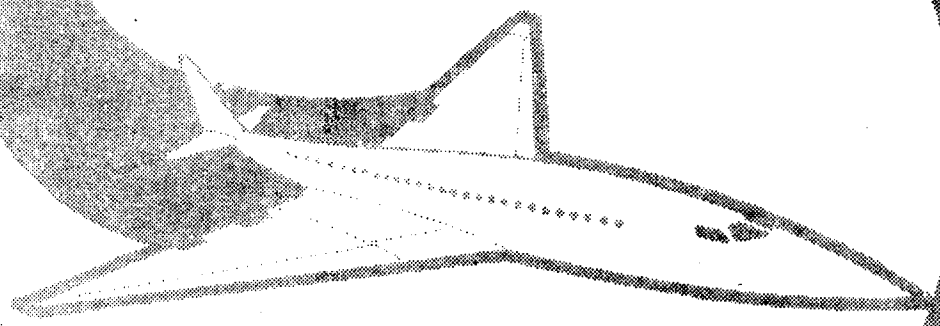
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DOT/FAA/CT-89/32

FAA Technical Center
Atlantic City International Airport
N.J. 08405

Fire Hazards of Aerosol Cans in Aircraft Cargo Compartments

David R. Blake



December 1989

Final

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U.S. Department of Transportation
Federal Aviation Administration

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16. Abstract

The purpose of this project was to determine the hazards associated with aerosol cans involved in cargo fires. Over the last several years the chlorofluorocarbon propellant used in aerosol cans has been replaced with hydrocarbons such as butane, propane, and isobutane. These flammable gases would normally be prohibited on passenger carrying airplanes but there is an exception for up to 75 ounces per person for medicinal and toilet articles when carried in checked baggage only. Seven fire tests involving aerosol cans were conducted in an 800-cubic-foot cargo compartment. The main conclusions of the study were that hydrocarbon propellants in aerosol cans increase the damage potential of luggage fires; the fires in a simulated Class D compartment where aerosol cans ruptured and ignited were not contained; a Class C compartment provides significantly more protection against aerosol can fire threat than does a Class D compartment; an aerosol can rupturing and igniting in a Class D or Class C cargo compartment would eliminate the compartment's ability to control ventilations and drafts; and aerosol cans would be exposed to elevated temperatures for a longer period of time in a luggage fire in a Class D compartment than in a Class C compartment.

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EXECUTIVE SUMMARY

The purpose of this project was to determine the hazards associated with aerosol cans involved in cargo fires and to determine the ability of Class D and Class C cargo compartments to contain those fires. Over the last several years the chlorofluorocarbon propellants used in aerosol cans has been replaced with hydrocarbons. The hydrocarbons used are typically a blend of butane, propane, and isobutane. These are classified as flammable gases are are normally prohibited from being carried on passenger airplanes. However there is an exception for medicinal and toiletries of up to 75 ounces net weight in checked baggage only. Aerosols are not permitted in carry-on baggage.

Seven fire tests were conducted on aerosol cans in an 800-cubic-foot cargo compartment. The cans were placed in burning luggage and exposed to 400-degree Fahrenheit air from a heat gun.

The study concluded that aerosol cans with hydrocarbon propellants increase the damage potential in luggage fires; the fires in a simulated Class D compartment where aerosol cans ruptured and ignited were not contained; Class C compartments provide significantly more protection than Class D compartments; an aerosol can rupturing and igniting in a Class C or Class D compartment would eliminate the compartment's ability to control ventilation and drafts; and aerosol cans would be exposed to elevated temperatures for a longer period of time in a luggage fire in a Class D compartment than in a Class C compartment.

INTRODUCTION

PURPOSE.

The purpose of this project was to experimentally determine the damage potential of aerosol cans with hydrocarbon propellants when involved in aircraft cargo compartment fires.

BACKGROUND.

Over the last several years the chlorofluorocarbon propellant used in aerosol cans has been replaced with hydrocarbons due to the environmental hazards associated with chlorofluorocarbons. The propellant used in many toiletry and household aerosols sold today is a combination of butane, propane, and isobutane. Title 49 Code of Federal Regulations (CFR) 175.101 contains a list of hazardous materials and their classifications. Butane, propane and isobutane are classified as flammable gases and are prohibited on passenger carrying aircraft. However, Title 49 CFR 175.101 provides an exception to this by permitting the carriage in checked baggage only of up to 75 ounces (net weight ounces or fluid ounces) of medicinal and toilet articles and aerosols, with no subsidiary risk, for sporting or home use. Aerosols are not permitted in the aircraft cabin.

The lower lobe cargo compartments on commercial transport aircraft are classified as either Class D or Class C. Class C compartments are required to have a smoke detection system, a fire suppression system, and the ability to limit airflow into the compartment. The suppression agent currently in use is Halon 1301. Class D compartments are not required to have smoke detection and fire suppression systems, instead they depend on relatively low leakage rates and small compartment volumes so that oxygen starvation controls any fires that are likely to occur. Both Class C and Class D compartments are designed to limit the leakage from the compartments but for different reasons. Class C compartments limit leakage so that after smoke detection and agent discharge, the agent concentration remains sufficiently high to suppress the fire until a safe landing can be made. Class D compartments limit leakage to starve a fire of oxygen. Since this is the only means of fire control it is more critical that Class D compartments remain tightly sealed than it is for Class C compartments. The full description of cargo compartment classifications is listed in appendix A. One additional design feature of many cargo compartments that is relative to this project is the ability of the compartment to rapidly relieve large pressure differentials between the compartment and passenger cabin. This feature is necessary in case of a rapid decompression that could occur if a cargo door failed in flight. Should this happen the cargo compartment liners on some airplanes are designed to separate from their fasteners relatively easily to equalize the pressure differential and prevent the cabin floor from being pulled down into the compartment.

DISCUSSION

TEST ARTICLE.

The test article used was the aft cargo compartment of a DC-10-30CF fuselage. The compartment volume was approximately 800 cubic feet. Galvanized steel was used as a cargo liner for the majority of the compartment. A 115- by 35-inch

section of fiberglass ceiling liner was installed directly above the area where the fires were to be started (figure 1). The edges of the fiberglass where notched and held in place with an aluminum strip that pressed the liner against the ceiling structure. This simulated a design used in some airplanes to allow the liners to pull free of the ceiling structure in the case of a decompression in flight.

In-flight air flow conditions were replicated in the fuselage. Ventilation was supplied to the cabin through two 10-inch perforated ducts that ran the length of the cabin at ceiling level. Air exited the cabin through vents in the lower sidewalls and an outflow valve located in the aft underside of the fuselage. The ventilation rate provided one change of cabin air approximately every 4 minutes.

A Halon 1301 fire suppression system was installed in the cargo compartment. The system was sized to provide an agent concentration of approximately 5 percent in the empty compartment through two nozzles in the compartment ceiling. A CO_2 fire suppression system was also installed in the compartment.

A total of five chromel/alumel thermocouples were installed on the cargo compartment ceiling: two of these were on the compartment centerline and three were on the section of fiberglass ceiling liner. A differential pressure transducer with a range of 0-1.0 psi was installed outside the cargo compartment and measured the difference between cargo compartment pressure and ambient. A smoke meter was also installed in the cargo compartment at ceiling level. Six additional smoke meters were installed in the cabin of the test article. They were placed at two stations in the cabin at three different heights for each station. The heights of the smoke meters were 25, 49, and 72 inches above the cabin floor. The concentrations of oxygen, carbon dioxide, carbon monoxide, and Halon 1301 were measured in the compartment at two different heights using Beckman infrared analyzers. The air inside the cargo compartment was also sampled by a Perkin-Elmer mass spectrometer that measured the concentrations of oxygen, carbon dioxide, propane, and butane. The thermocouple, smoke meter and infrared analyzer data were sampled and recorded every 5 seconds. The pressure transducer data were recorded continuously, and the mass spectrometer data were recorded approximately every 30 seconds. Figures 1, 2, and 3 show the location of the instrumentation and the fire load in the test article.

TEST RESULTS.

A total of seven tests were conducted on aerosol cans. Five tests were conducted with aerosol cans in a burning suitcase in the cargo compartment. For these tests, either one or two aerosol cans were placed in a suitcase filled with rags, newspaper, and a small amount of alcohol. This was ignited with nichrome wire. This suitcase was placed among several other suitcases filled with rags to simulate a bulk-load cargo compartment. A partially loaded cargo compartment was simulated by filling approximately 40 percent of the compartment volume with cardboard boxes filled with packing foam. These boxes were used to displace air in the compartment and were not involved in any of the fires. A ceiling mounted photoelectric smoke detector was installed in the compartment for each of the first three tests. Two additional tests were conducted using a heat gun to heat the cans until they burst. Halon was discharged into the compartment before the can burst for one test but no halon was discharged for the other test. Oil burner electrodes were placed in the cargo compartment and energized for both of these tests. The following is a brief description of test conditions and results.

Test 1. One 9-ounce hair spray can and one 4-ounce deodorant can in burning suitcase. The smoke detector alarmed at 1 minute, 13 seconds (1:13). The cans had not exploded when the test was terminated at 12 minutes with the CO_2 suppression system. The test was terminated because of poor visibility in the compartment after 12 minutes.

Test 2. One 9-ounce hair spray can and one 4-ounce deodorant can in burning suitcase. The smoke detector alarmed at 40 seconds. The first can exploded at 3:20 with an overpressure of 0.08 pounds per square inch (psi). The second can exploded at 3:34 with an overpressure of 0.30 psi. Halon was discharged into the compartment at 3:42 and extinguished the fire. A small section of the fiberglass ceiling liner was pushed into the space between the compartment ceiling and the cabin floor. This left an opening in the compartment ceiling of approximately 1/2 square foot.

Test 3. One 9-ounce hair spray can and one 4-ounce deodorant can in burning suitcase. The smoke detector alarmed at 45 seconds. The first can exploded at 4:49 with an overpressure of 0.52 psi. The second can exploded at 5:17 with an overpressure of 0.08 psi. CO_2 was used to extinguish the fire at 5:57. There was extensive smoke in the cabin at that time. Approximately 1.5 square feet of ceiling liner was forced out of its holder. The test article was damaged in several areas as a result of this test. A section of cabin floor was blown out, and a fireball was visible in the cabin. A door to the cargo compartment was blown open, and the aluminum structure that was used to close off the end of the fuselage was forced open in several places. Figure 4 shows the initial explosion in the cabin. The frames are 1/8th of a second apart.

Test 4. One 9-ounce can of hair spray in burning suitcase. Can exploded at 5:19 with an overpressure of 0.18 psi. CO_2 was used to extinguish the fire.

Test 5. Two 9-ounce hair spray cans in burning suitcase. The first can exploded at 2:22 with an overpressure of 0.25 psi. The second can exploded at 3:25 with an overpressure of 0.04 psi. CO_2 was used to extinguish the fire.

Test 6. One 7-ounce can of air freshener exposed to 400-degree Fahrenheit (^{o}F) air from a heat gun. Halon was discharged into the compartment at 3 minutes. The can burst at 6:26, but the contents did not ignite and no overpressure was recorded. The halon concentration at the time the can burst was approximately 4.5 percent. The oil burner electrodes were energized for the entire test.

Test 7. One 7-ounce can of air freshener exposed to 400 ^{o}F air from a heat gun. Halon was not discharged into the compartment for this test. The can burst at 5:04 and the contents ignited in a fireball. The ignition point of the escaping gas was near the bottom of the can and not at the oil burner electrodes. No overpressure was recorded. The boxes near the can burned briefly after the fireball subsided and then self-extinguished.

The test scenarios were chosen to determine the ability of Class C and Class D cargo compartments to control fires involving aerosol cans. Figure 5 is a graph of the temperature on the ceiling of a simulated Class D cargo compartment taken from reference 1. As can be seen from the graph, the temperature on the ceiling with fiberglass liners and no forced air into the compartment was still above 700 ^{o}F 15 minutes after the start of the fire. From that it can be concluded that aerosol cans could be subjected to elevated temperatures for at least 15

minutes in a Class D compartment before oxygen starvation controls the fire. During the five tests with aerosol cans in a burning suitcase, the cans exploded in four tests. Test 1 was terminated after 12 minutes without the cans exploding. In the remaining four tests the earliest the cans exploded was 2:22 seconds and the latest explosion was at 5:19 seconds. In all four of these tests the cargo liners were forced out of their holders which allowed cabin ventilation air into the compartment. In tests 6 and 7, the cans were heated with 400 ^{o}F air and ruptured at 6:26 and 5:04. In all six tests where the cans ruptured, they did so well before the 15 minutes that was needed to control a luggage fire in a simulated Class D compartment (reference 1). If an aerosol can did rupture in a Class D cargo compartment, it is likely that the liners would be opened up and the fire containment ability of the compartment would be eliminated. Figure 6 shows the level of smoke in the cabin after the cans exploded in test 3.

Previous fire testing has also been conducted on Class C cargo compartments (reference 2). Two of the conclusions from that work were:

1. The halon extinguishing system effectively suppressed the initial flames and effectively controlled the fire provided that ceiling liner burnthrough did not occur.

2. The smoke detection system did not always give early warning of fire and, subsequently, gave false indications of the levels of smoke in the compartment.

Table 1 is taken from reference 2 and shows the times for smoke detection in a simulated Class C compartment with burning luggage. The times for smoke detection ranged from 10 seconds to 250 seconds with an average time of 122 seconds. The earliest time for a can to rupture in the six tests where rupture occured was at 142 seconds. Using this approach it can be stated that it is likely that smoke detection would occur and the fire successfully suppressed before a can would rupture. This is assuming that the halon was discharged shortly after smoke detection and that ceiling liner burnthrough did not occur.

In the case where a can ruptured before halon discharge, it was shown in test 2 that the subsequent discharge of halon extinguished the fire. However, in that test the cargo liners were forced out of the holders and agent concentration was not maintained as designed. Figure 7 shows the decay of extinguishing agent for the empty, sealed compartment without a fire and for the loaded compartment after the can exploded in test 2. The concentration in the graphs is the average of the two sampling ports.

Test 6 shows that should a can rupture after halon discharge, due to a smoldering fire for example, the halon would prevent the ignition of the escaping propellant. Figures 8 shows the rupture of the aerosol can during test 6.

In test 7 the can was heated in the same manner as test 6 but halon was not used. The can ruptured and the contents ignited in a fireball. The ignition point was near the can and not at the location of the oil burner electrodes. Figure 9 shows the rupture and ignition of the can in test 7. This test demonstrated that an external ignition source is not needed to ignite the propellant; the heat from the ruptured can was sufficient to ignite the contents.

CONCLUSIONS

1. The use of hydrocarbon propellants in aerosol cans increases the damage potential of luggage fires in aircraft cargo compartments.

2. Aerosol cans ruptured and ignited in a buring suitcase in a simulated Class D cargo compartment in tests 3, 4, and 5. In those tests the the cargo liners separated from the fasteners and the fires were not contained.

3. Class C cargo compartments provide significantly more protection against fires involving aerosol cans than Class D cargo compartments.

4. An aerosol can rupturing and igniting in a Class C or Class D cargo compartment would eliminate the ability of the compartment to control ventilation and drafts.

5. Aerosol cans would be exposed to elevated temperatures for a longer period of time in a luggage fire in a Class D compartment than in a Class C compartment due to the amount of time it takes for oxygen starvation to suppress a luggage fire. This increases the likelihood that an aerosol can would rupture and ignite in a Class D compartment.

REFERENCES

1. Blake, D.R. and Hill, R.G., Fire Containment Characteristics of Aircraft Class D Cargo Compartments, FAA Technical Report No. DOT/FAA/82-156, March 1983.

2. Blake, D.R., Suppression and Control of Class C Cargo Compartment Fires, FAA Technical Report No. DOT/FAA/CT-84/21, Feburary 1985.

TABLE 1. SMOKE DENSITY IN COMPARTMENT

TEST	ALARM TIME (SECS)	SMOKE DENSITY AT ALARM (% LIGHT TRANSMISSION)	DE-ALARM TIME (SECS)	SMOKE DENSITY AT DE-ALARM (% LIGHT TRANSMISSION)
1	71	99	629	47
2	87	93	1065	32
3	25	96	863	60
4	85	96	602	65
5	206	*	**	**
6	173	70	**	**
7	100	99	474	*
8	112	99	**	**
9	99	99	**	**
10	76	99	3460	57
11	59	99	**	**
12	162	90	**	**
13	250	92	**	**
14	119	99	**	**
15	214	62	490	64
16	119	100	2130	53
17	93	96	3430	98
18	178	84	230	26
19	185	66	210	35
20	140	94	180	32
21	10	100	240	72
22	58	99	207	87
23	186	95	270	80
Average	122			

* Smoke meter data not available
** Detectors did not de-alarm

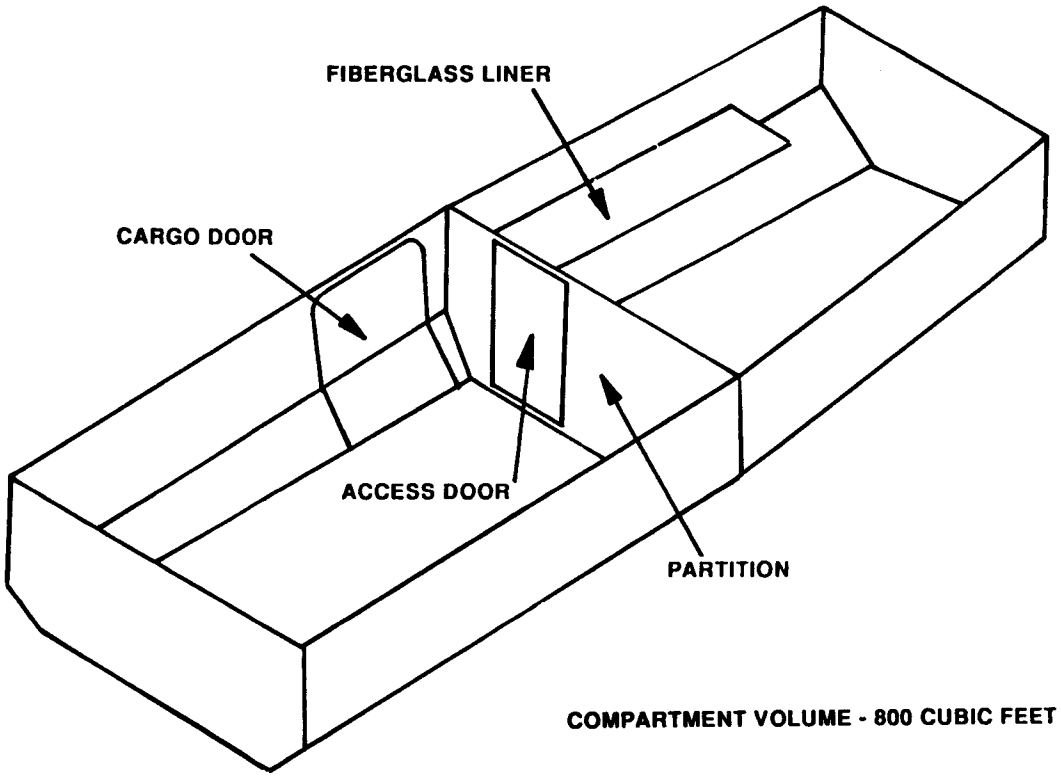


FIGURE 1. TEST ARTICLE

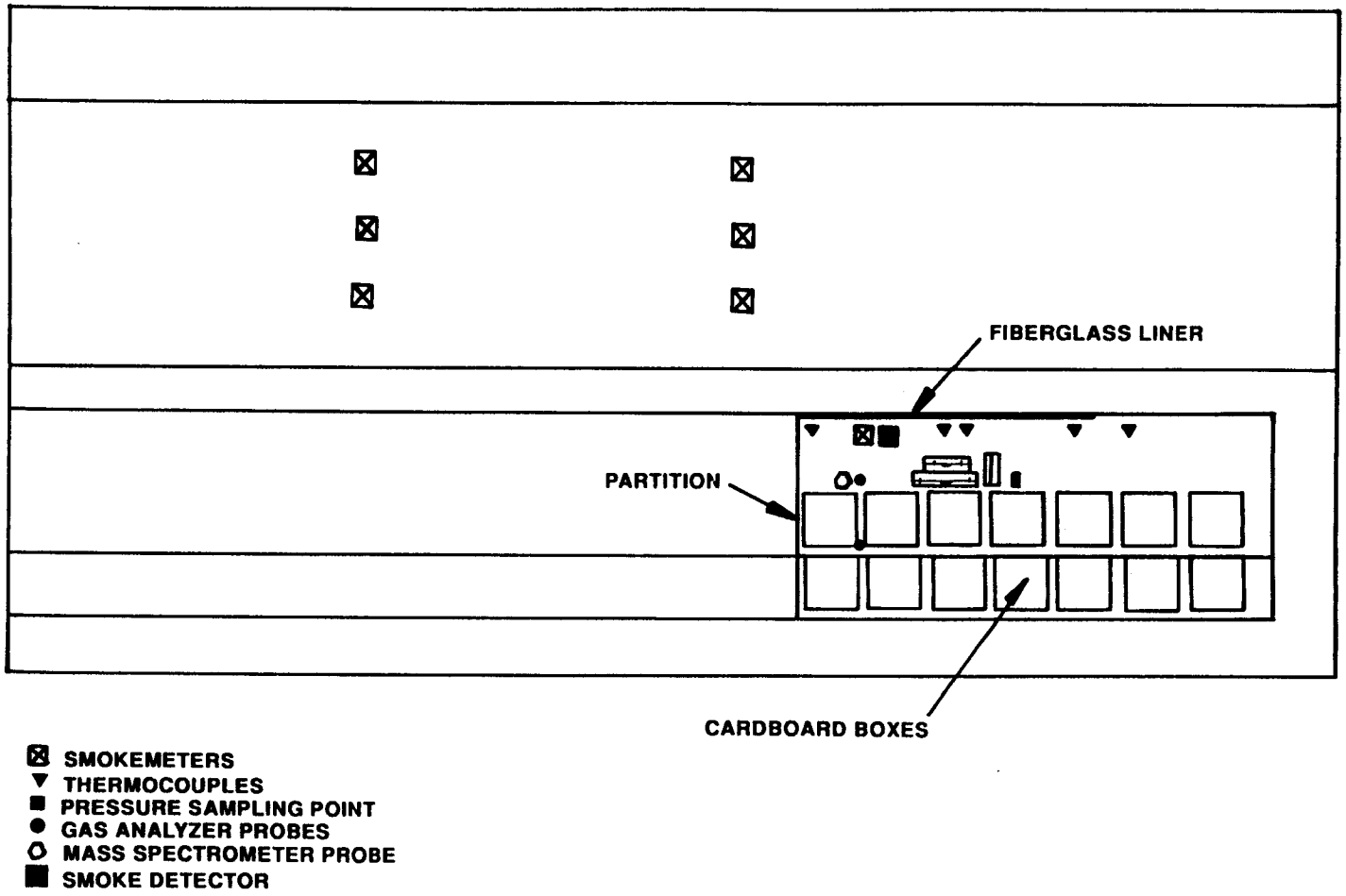
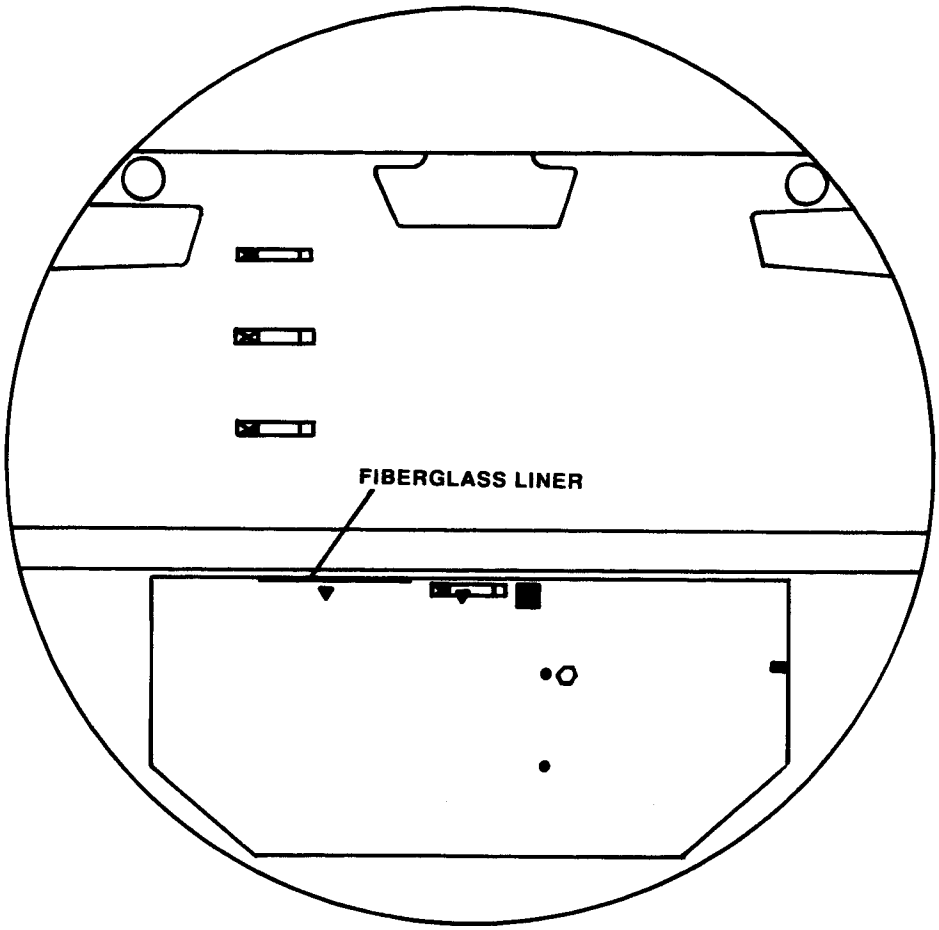
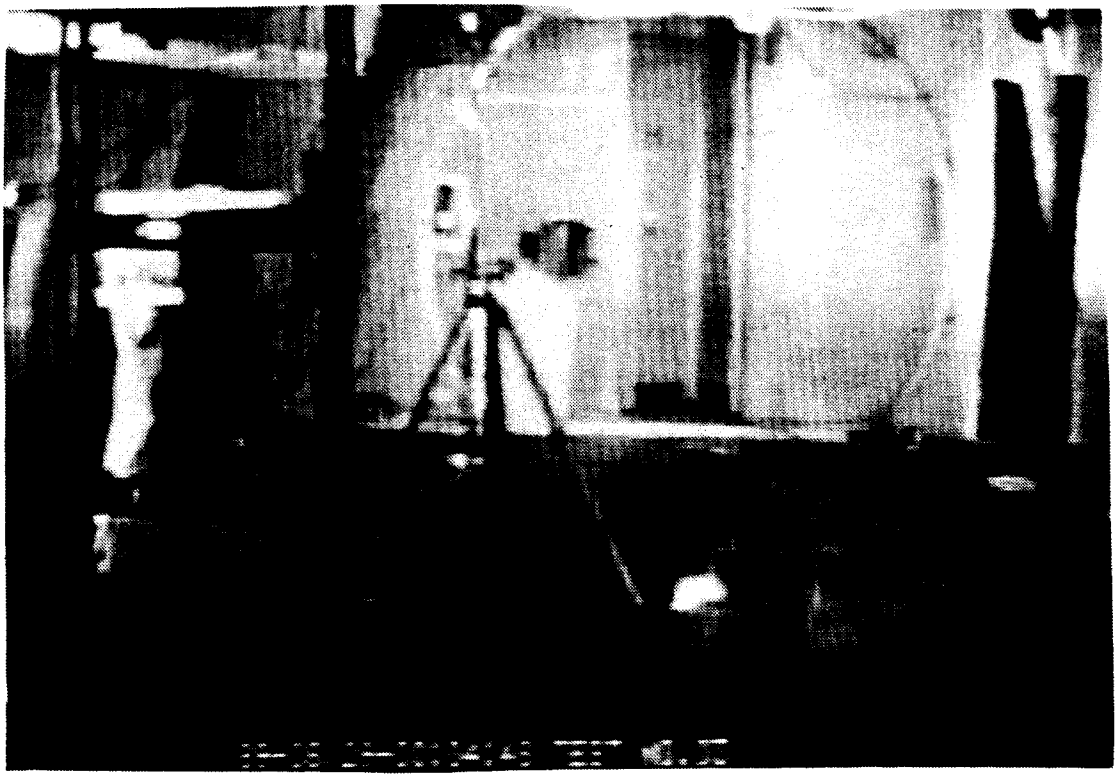


FIGURE 2. INSTRUMENTATION LOCATION - SIDE VIEW



⊠ SMOKEMETERS
▼ THERMOCOUPLES
■ PRESSURE SAMPLING POINT
● GAS ANALYZER PROBES
○ MASS SPECTROMETER PROBE
■ SMOKE DETECTOR

FIGURE 3. INSTRUMENTATION LOCATION - END VIEW



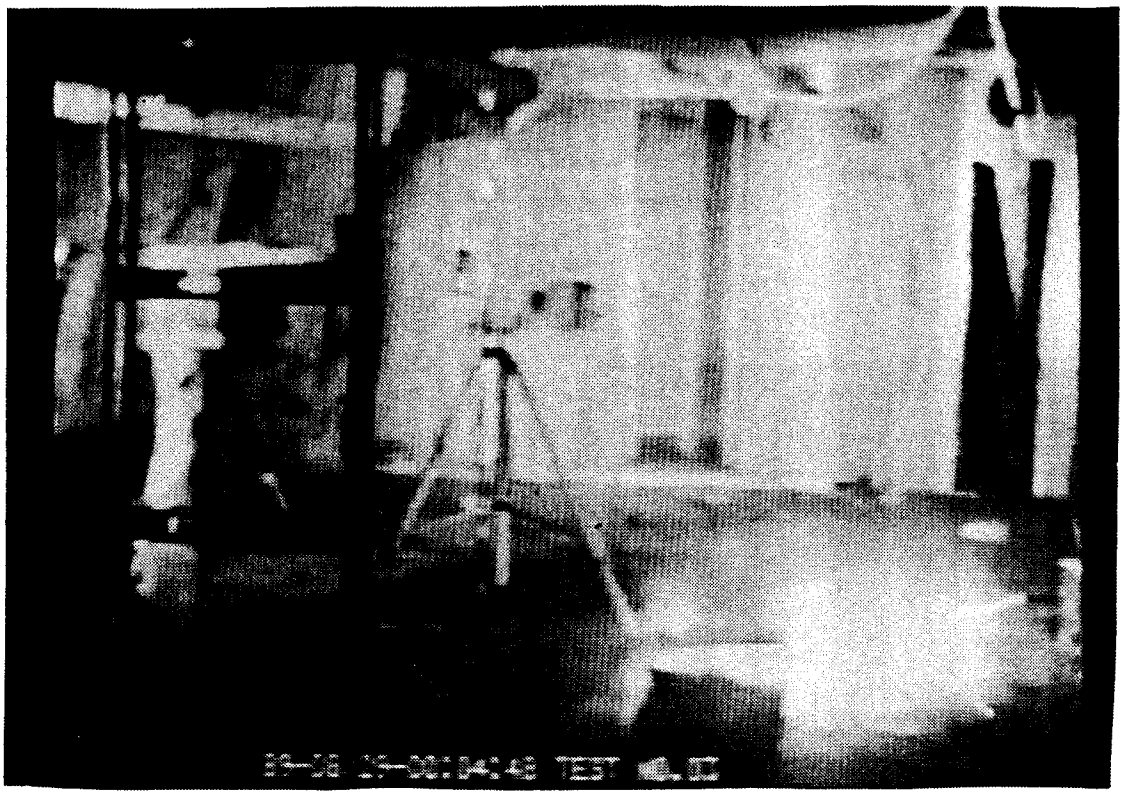


FIGURE 4. CABIN VIEW OF EXPLODING CAN - TEST 3 (1 of 2 Sheets)

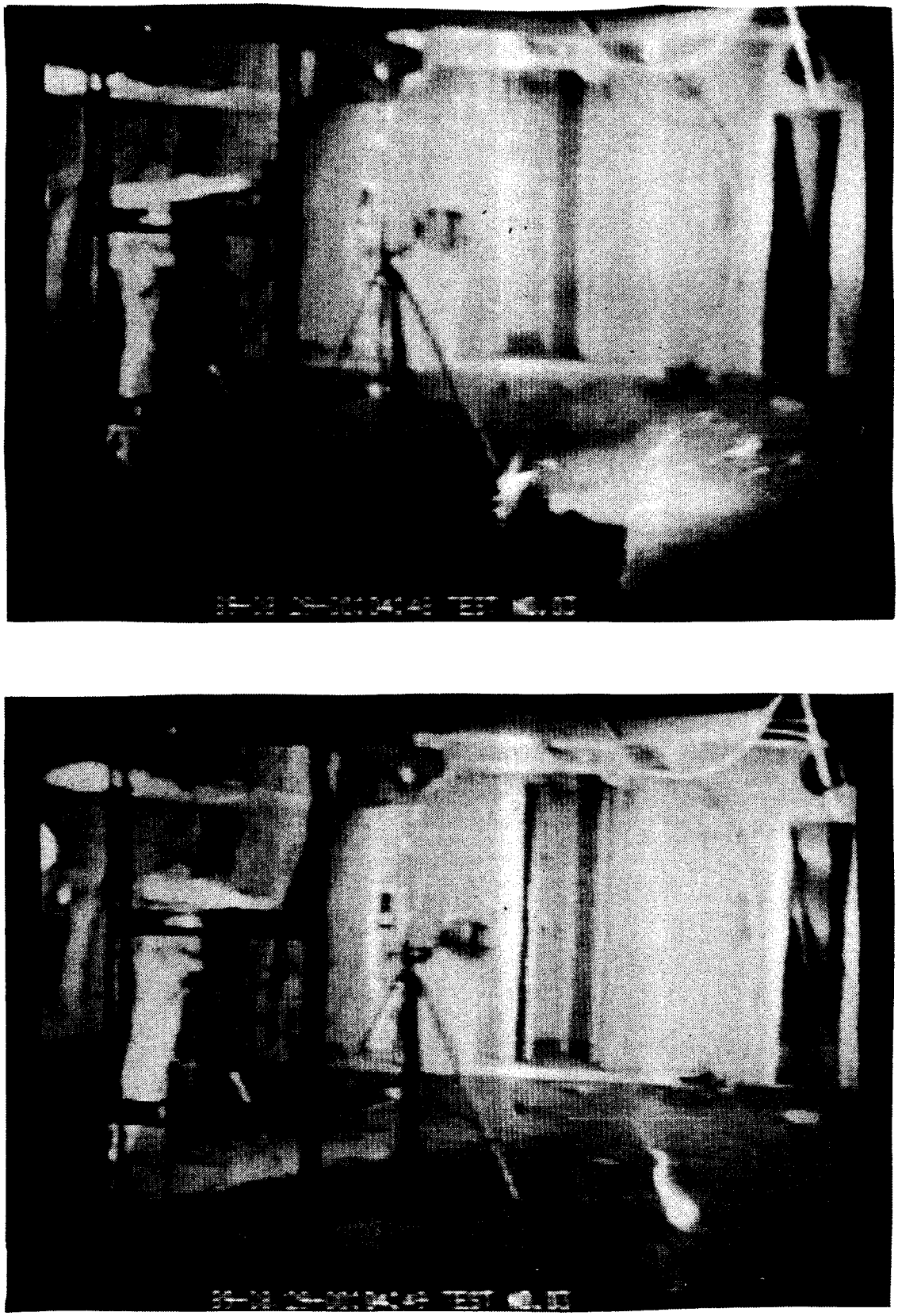


FIGURE 4. CABIN VIEW OF EXPLODING CAN - TEST 3 (2 of 2 Sheets)

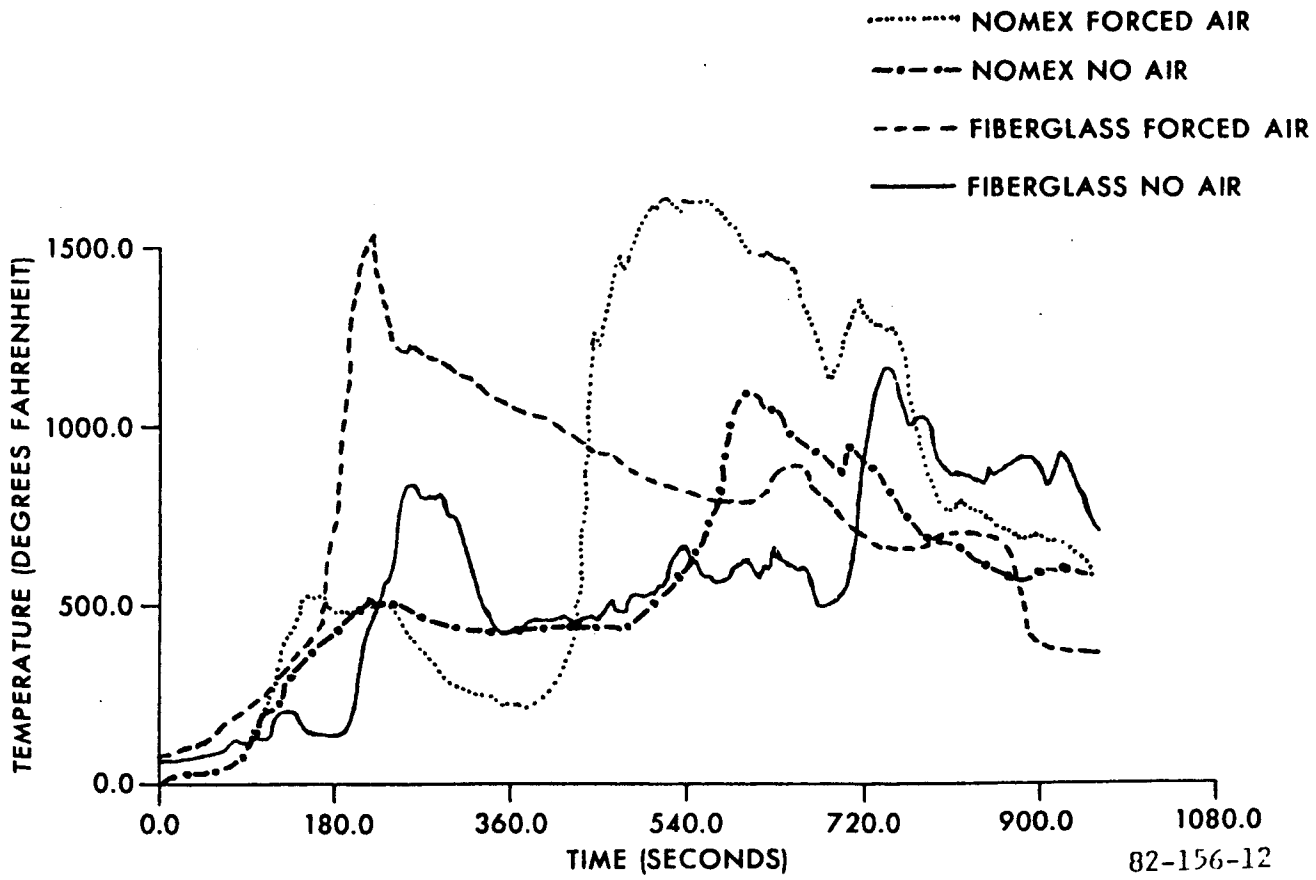


FIGURE 5. BELOW CEILING TEMPERATURES

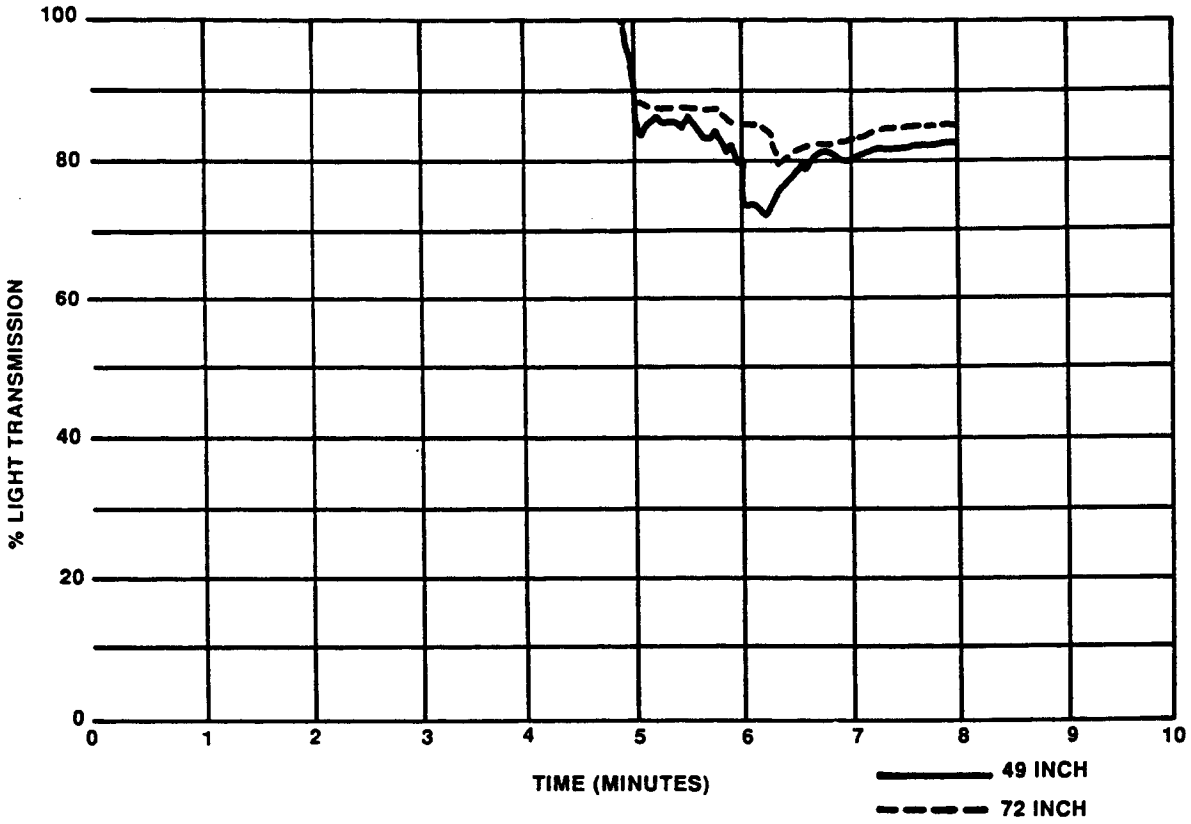


FIGURE 6. MID-CABIN SMOKE - TEST 3

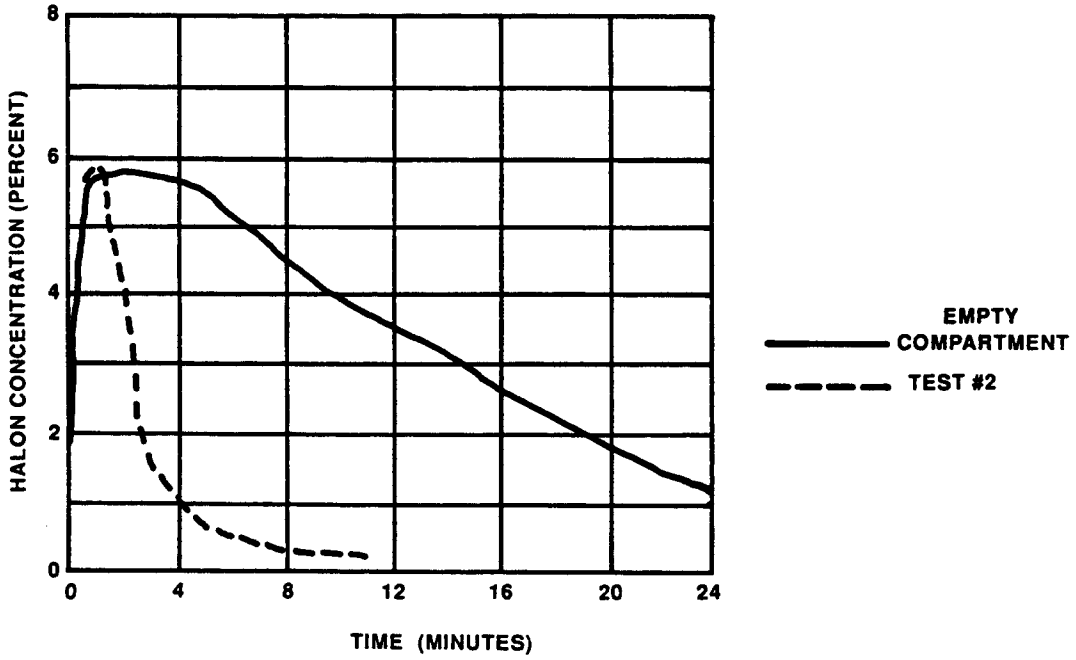


FIGURE 7. HALON CONCENTRATION

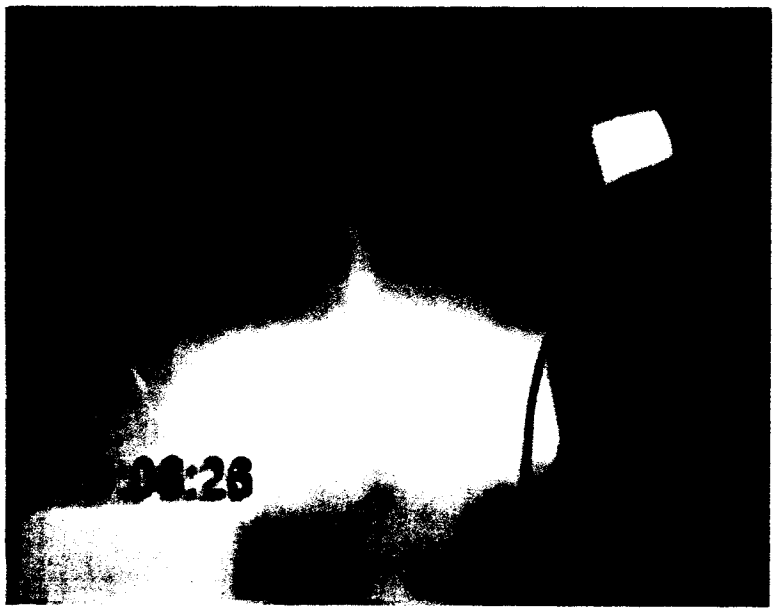
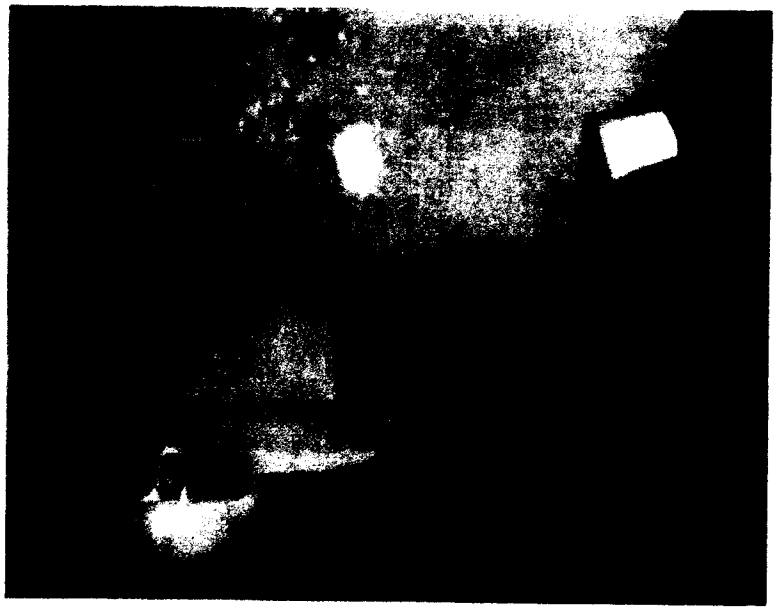




FIGURE 8. CAN RUPTURE - TEST 6 (1 of 2 Sheets)



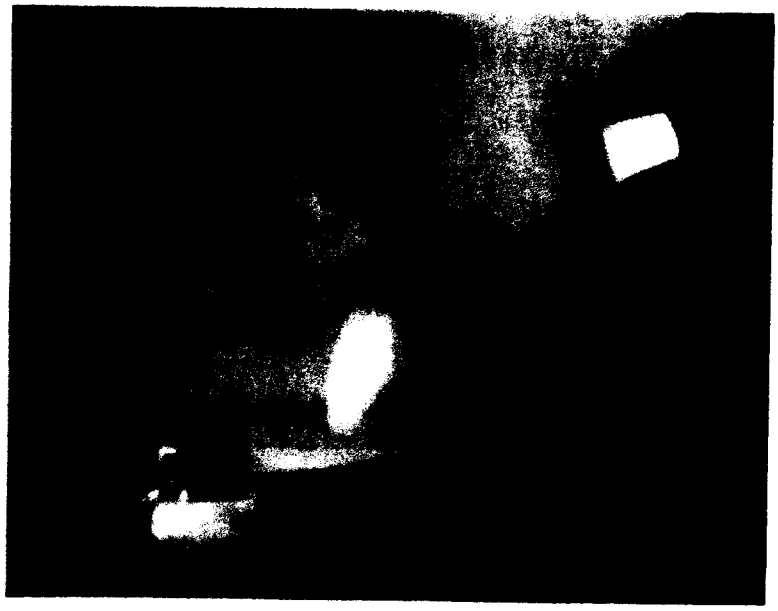


FIGURE 8. CAN RUPTURE - TEST 6 (2 of 2 Sheets)

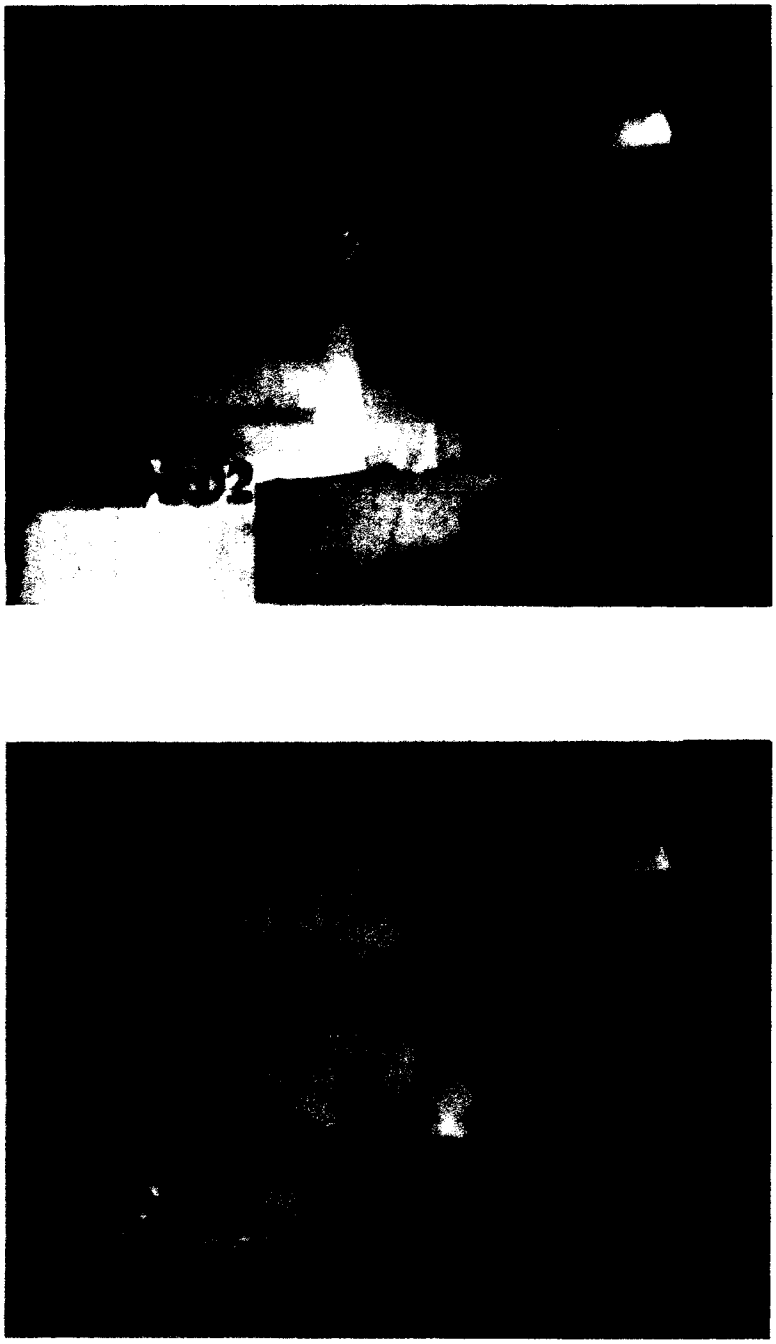
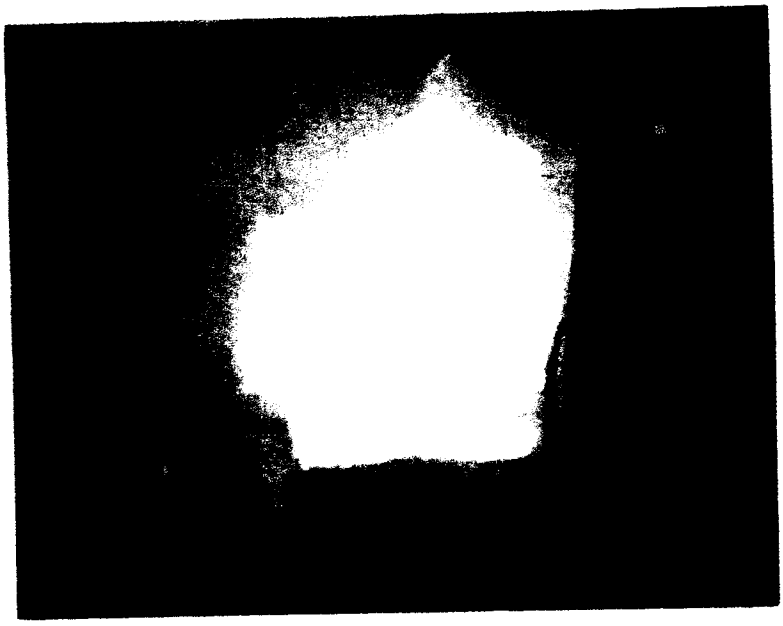


FIGURE 9. CAN RUPTURE - TEST 7 (1 of 2 Sheets)



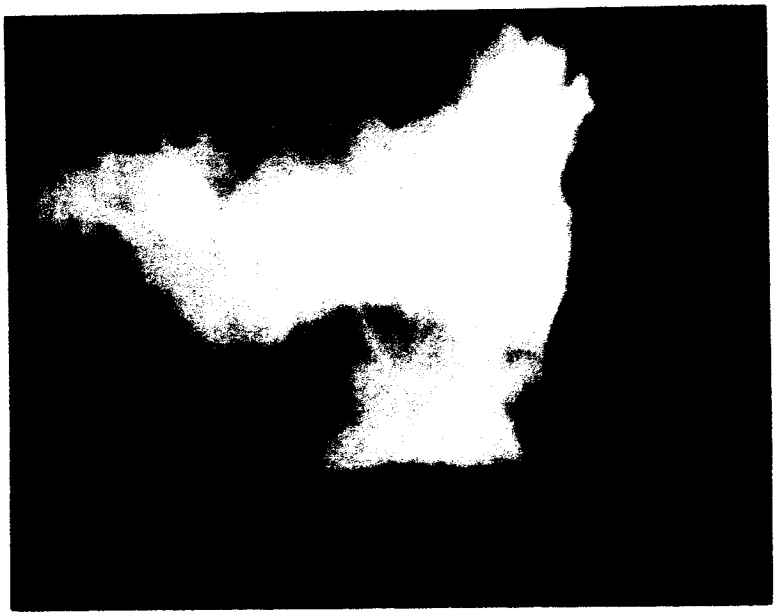


FIGURE 9. CAN RUPTURE - TEST 7 (2 of 2 Sheets)

APPENDIX A

CARGO COMPARTMENT CLASSIFICATION FAR 25.857 CLASSES A THROUGH E

Class A

A Class A cargo or baggage compartment is one in which (1) the presence of fire would be easily discovered by a crew member while at his station; and (2) each part of the compartment is easily accessible in flight.

Class B

A Class B cargo or baggage compartment is one in which (1) there is sufficient access in flight to enable a crew member to effectively reach any part of the compartment with the contents of a hand-held fire extinguisher; and (2) when the access provisions are being used, no hazardous quantity of smoke, flame, or extinguishing agent will enter any compartment occupied by the crew and passengers; (3) there is a separate, approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.

Class C

A Class C cargo or baggage compartment is one not meeting the requirements for either Class A or 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; and (4) there are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fires that may start within the compartment.

Class D

A Class D cargo or baggage compartment is one in which (1) a fire occurring in it will be completely confined without endangering the safety of the airplane or the occupants; (2) there are means to exclude hazardous quantities of smoke, flames, or other noxious gases, from any compartment occupied by the crew or passengers; and (3) ventilation and drafts are controlled within each compartment so that any fires likely to occur in the compartment will not progress beyond safe limits; and (4) consideration is given to the effect of heat within the compartment on adjacent critical parts of the airplane.

For compartments of 500 cubic feet or less, an airflow of 1500 cubic feet per hour is acceptable.

Class E

A Class E cargo compartment is one on airplanes used only for the carriage of cargo and in which (1) there is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station; (2) there are means to shut off the ventilating airflow to, or within, the compartment, and the controls for these are accessible to the flight crew in the crew compartment; (3) there are means to exclude hazardous quantities of smoke, flames, or noxious gasses from the flight crew compartment; and (4) the required crew emergency exits are accessible under any cargo loading condition.

Potential for Ignition of Flammable Aerosol Propellents by Static Electricity Inside Checked Baggage

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Introduction

This study was requested by the Federal Aviation Administration. The purpose of this study was to review the various incidents involving air transport of aerosols with flammable propellants that have resulted in fire accidents or explosions and suggest what phenomenon likely caused these events to occur.

Investigated Incidents

Aerosols are prohibited on passenger aircraft as carry-on items (CFR-49). An exception of up to 70 ounces by mass or 68 fl oz by volume per person for toilet and medicinal articles is in 49 CFR 175.10. They are allowed in carry-on or checked baggage presently. They are not prohibited.

An exception of up to 70 ounces by mass or 68 fl.oz. by volume per person for toilet and medicinal articles is allowed, but only in checked baggage that is stowed in aircraft cargo holds. The FAA has investigated several incidents dealing with explosions and fires related to aerosols. FAA reports documented the following examples:

● On 5/29/98, a 180 ml aerosol can of hair-spray (considered hazmat Class 9) exploded on an Air Transat flight upon arriving at the Toronto airport. The cause was not given.

● On12/22/02, the nozzle on an aerosol can of hair-spray blew off at the Ottawa airport in Ontario during unloading from a West Jet flight. Witnesses saw a blue flame coming out of the end of a nylon shoulder bag after it struck the carousel bumper at the end of the conveyor chute. There was a small fire, but no explosion. The bag contained a book, a fur hat, slippers, the can of hair-spray, and various other articles. The suspected cause was the release of flammable propellent from the aerosol can and subsequent ignition by static electricity. The investigating team tested and verified the possibility of ignition of the hair-spray by an electric arc.

● On 5/11/03, a hard plastic carrying case exploded when it was dropped into the cargo hold of a United Airlines flight in San Francisco. The case contained electronics with no ignition source (like batteries). The case was lined with foam that was glued on using caulk tubes of Liquid Nails and TiteBond adhesive. The case was closed immediately after gluing. Although the case contained a breather valve, fumes from the adhesive were still present after the explosion. The suspected cause was ignition of the flammable fumes by static electricity. Liquid Nails and TiteBond MSDS's list these products as ORM-D's and warn that the vapors are extremely flammable and may cause an explosive flash fire if exposed to an ignition source like a spark.

● The FAA conducted a study that subjected aerosol cans to heat from luggage fires and from a heat gun in class C and D cargo holds on commercial jets. The FAA report FAA/DOT/CT-89/32 documented the results. Five of seven tests placed aerosol cans in already burning suitcases and the remaining two tests exposed them to a 400^{o}F heat

gun. All of them exploded in about 5 minutes. The study concluded that fire detection and suppression systems in these cargo areas were not sufficient to contain the fire.

● In February, 2003 a suitcase exploded as it arrived at the bottom of a conveyor belt after check-in at Boston airport.





● This year (2004), an aerosol can of Suave hair-spray exploded, ripping a nylon carry-on bag apart (below).





Other incidents involving the explosion of aerosols not related to air transport can be found in the appendix of this report. These incidents involved aerosols used for tire inflators, spray paint, air freshener, hairspray and insecticide.

Aerosol Hazard

It is possible for the cap on an aerosol can in baggage to pop off as a result of normal handling, especially during loading and unloading. It is easily demonstrated that the caps on many aerosol containers can be made to pop off by simply tipping the can over on a hard floor. Their relative weight compared to other items in a suitcase and their long slender shape make aerosols likely to move around inside baggage. During transportation, they will tend to settle to the lowest point, where they will likely come in contact with either the hard wall of a suitcase or the floor itself if in the cloth luggage.

Once the cap comes off, subsequent impacts on the spray nozzle can release the contents. It is easily demonstrated that the spray nozzle on most aerosol cans can be depressed by dropping the aerosol can upside down onto a hard floor from less than an inch. A quantity of propellent is released along with the product when the spray valve is depressed, so the potential for dispensing flammable gases into the trapped airspace within luggage, in sufficient quantity (typically 2 - 10% by volume) to form an ignitable mixture, is significant. This effect is amplified in a low pressure environment like an aircraft.

The propellents present in aerosols depend on their application. Chlorofluorocarbons (CFC's) have been replaced by hydrocarbons, typically liquified petroleum gas (LPG), as the main propellent in aerosols (http://www.yorks.karoo.net/aerosol/link4.htm). LPG is a blend of the flammable gases butane and propane. Household aerosols use mainly LPG but sometimes use compressed air and nitrogen, which are not flammable. Personal care products often use dimethyl ether, another flammable propellent, but sometimes use compressed carbon dioxide, which is not flammable.

The flammability of a propellent is in part described by its "flash point". The flash point is the lowest temperature at which the propellent forms an ignitable mixture in air (http://www.ilpi.com/msds/ref/flashpoint.html).

The lower the flash point, the easier it is to ignite the mixture. Flash points for common propellents are listed in Table 1.

Table 1

propellent	flash point (ºF)
butane	-76
propane	-156
dimethyl ether	- 42
liquid nails	1

Source of Ignition

The suspected source of ignition in the FAA documented incidents a spark, also referred to as an ESD (electostatic discharge), caused by the "tribo-electric charging" or rubbing together of two dissimilar materials. Tribo-electric charging is the transfer of electrons that takes place naturally by either rubbing action, or by simple contact and separation. The amount of charge buildup depends on the nature of the two materials in contact and the humidity in the air. High humidity tends to inhibit charge buildup.

NASA has found charge buildups amounting to 20,000 volts by rubbing synthetic fabrics together. Voltages associated with other situations are shown below.
http://www.planet-stuff.freeserve.co.uk/Standards/Component_Handling.htm
http://www.amasci.com/emotor/voltmeas.html

Means of Static Generation	Voltage Produced	
	10 - 20% RH	65 - 90% RH
Rubber comb thru dry hair	50,000	2500
Rubber shoes on carpet	35,000	1500
Desk chair rolling on plastic floor mat	20,000	1500
Common plastic bag picked up from bench	20,000	1200
Walking across vinyl floor	12,000	250
Paper placed in vinyl envelopes	7,000	600
Unroll plastic tape	5,000	500

In order for the tiniest of sparks to occur, the charge needs to be at least 500 volts. In view of the table above, ignition of flammable vapors inside luggage can easily occur under dry conditions. (http://www.amasci.com/emotor/voltmeas.html http://www.amasci.com/emotor/voltmeas.html).

The relative humidity (RH) of the air inside an airplane is typically very low. In many cases it approaches single digit RH's, especially on high altitude flights. So the conditions on aircraft appear to be conducive to static charging. (http://www.allergyconsumerreview.com/relative-humidity-airplanes.html http://www.flyana.com/dehydration.html).

Tribo-charging materials

The tendency for two materials in contact to become charged depends on many factors. The "triboelectric chart" below shows these tendencies.

The further apart two materials are on this chart, the more readily they tend to become charged. Glass or clothing in contact with many of the plastics used in packaging (polyethylene, polypropylene) are examples of materials that readily acquire a charge. Reference Site: http://www.esdjournal.com/static/refuelfr.htm

Table 2 lists the Triboelectric Series.

Table 2: Triboelectric Chart

Positive Charge	Dry Human Skin
+	Asbestos
+	**Leather** (clothing/shoes)
+	Rabbit Fur
+	Acetate
+	**Glass** (bottles)
+	Human Hair
+	**Nylon** (clothing)
+	**Wool** (clothing)
+	**Fur** (clothing)
+	Lead
+	**Silk** (clothing)
+	**Aluminum** (aerosol containers)
+	Paper
+	**Cotton** (clothing)
neutral	Steel
-	Wood
-	Sealing Wax
-	**Hard Rubber** (shoes)
-	Mylar
-	Nickel, Copper
-	Silver
-	Brass
-	Gold, Platinum
-	**Polyester** (clothing)
-	Celluloid
-	Styrene
-	**Orlon** (clothing)
-	**Acrylic**
-	Saran
-	**Polyurethane** (foam)
-	**Polyethylene** (tape)
-	**Polypropylene** (plastics)
-	**PVC (Vinyl)**
Negative Charge	Silicon Teflon

GENERAL OBSERVATIONS

1. The presence of apparel products (wool, silk, polyester) in checked baggage (plastic lined insides) can result in charge build up due to static electricity resulting from vibration during air transportation and baggage sorting. The presence of these charges can result in an Electrostatic Discharge (ESD) or “sparks” which can cause ignition of fuel source.

2. Aerosol containers used for consumer products such as hair spray can contain highly flammable propellants. The dispensing valves in these cans are not tested to the same level of air transportation requirements as the individual cans themselves. As a result these valves can slowly leak during vibration in a low pressure environment.

3. The over-caps on consumer aerosols are “snap-fit” and can easily become dis-engaged from the can top resulting in direct exposure of the valve.

4. The consumer packaging industry currently does not have economically feasible air-eligible aerosol containers that will prevent leakage of the propellant.

5. Alternate pump types of dispensing packaging are available for similar products like hair spray that do not use highly flammable propellants.

6. ESD incidents are more prevalent during low humidity conditions (winter months) when sustained vibration (rubbing) is present.

CONSIDERATIONS

- i It is impossible to avoid incidents involving charge build up in checked baggage due to the nature of apparel products. The only way to provide complete safety is to **ban** all air transportation of flammable aerosols (eliminate the fuel source).

- i Consumer products in aerosols such as hair-spray are available in safe pump types of dispensing packages that do not have flammable propellants. Such primary packaging should be labeled "**air-eligible**".

- i Existing consumer products in aerosol can designs with flammable propellants should be labeled "**not eligible for air shipments**".

Appendix - Other Incidents

(http://www.chemaxx.com/aerosol5.htm)

Aerosol Propellant (propane/ butane) Fire - Spray Paint - Arizona



A woman was severely burned when a small wooden shelf, containing an aerosol can of spray paint, fell from the wall in her laundry room. Upon impact with the laundry room floor and being hit by the shelf, the can was punctured, thereby releasing flammable solvents and propane propellant, which were ignited by a pilot light in the gas clothes drier. The technical issues involved concerned identifying the manufacturer of the spray paint (the aerosol can was disposed of by the fire department) and determining the safety and integrity of aerosol containers.

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Aerosol Propellant (propane/ butane) Fire - Tire Inflator - California



A California woman and two teenage girls were badly burned when an aerosol tire inflator product may have ignited inside the back of a station wagon they were driving. There were no fatalities, but one of the teenage girls was severely burned and incurred over $1.0 million in medical expenses. The station wagon was completely destroyed by the fire and the surface of the aerosol container was burned and corroded to the point that product identification was completely removed.

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Aerosol Air Freshener Explosion – Texas

A Spanish woman was about to use an aerosol air freshener for the first time. She had some difficulty removing the large plastic over cap. As she struggled to remove the plastic over cap, the can bottom suddenly exploded off creating a rocket effect. It is believed that the body of the can struck her eye, causing her to lose the eye.



Click Picture to View Test Explosion. Video will download initially one frame at a time, then will play normal speed.

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Aerosol Spray Paint Fire and Burns - Indiana #1

A woman was preparing to spray paint wicker furniture. Following logo-type instructions on the aerosol cap, she attempted to remove the cap with a screwdriver. The screwdriver punctured the can and it suddenly released all it contents into the room. A pilot light on a gas water heater ignited the propane/butane propellant and flammable solvents. The woman received severe burns on her legs and feet.



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Aerosol Spray Paint Fire and Burns - Indiana #2

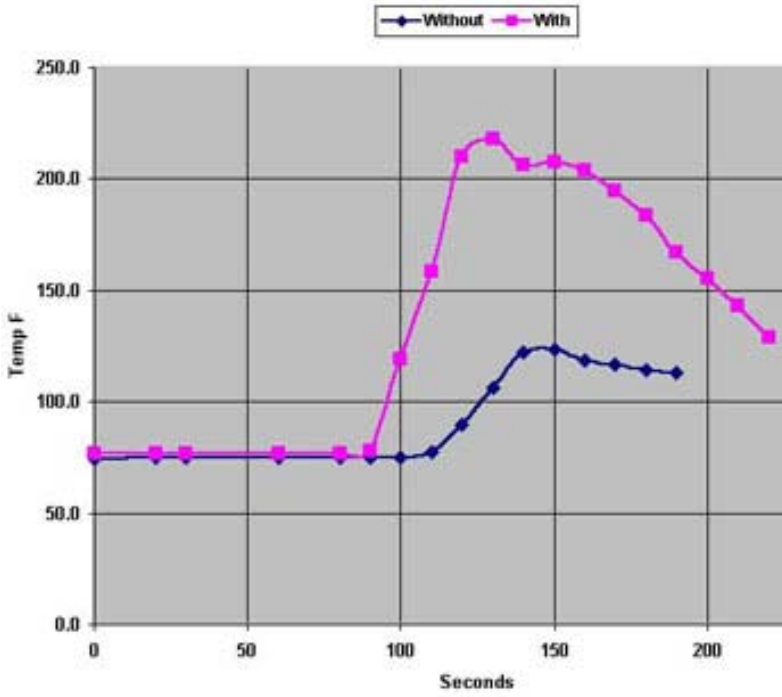
A gentleman and his wife had decided it was a good autumn day to touch up some of the wheels on their RV with spray paint, and to also paint a small table and chairs used by their grandchildren. This work was to be done outside, but the tools and spray paints were inside a (non-attached) workshop. The gentleman went into his workshop and gathered up sanding tools, sand paper and the can of paint. As he was walking toward the door of his workshop he began shaking the can of paint. As he walked past a wood-burning stove, the can exploded and he was engulfed in a ball of fire.



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Aerosol Hairspray Burns - Arizona

A woman had sprayed her hair early in the morning with a hair spray product consisting mostly of mineral oils. **The instructions on the container were to leave the product on the hair (soak) for a period of time (30 minutes).** The woman gathered her children, put them in her car, and then drove them to day care. When she lit a cigarette, her hair lit up into flames



Burning behavior of hair with & without hairspray product applied.

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Aerosol Hair Spray Fire - Georgia

A 70-year old woman Judge was preparing herself for the day in her bathroom at her home. She either dropped or knocked over a large aerosol hair spray. When the aerosol fell, it impacted on something that punctured it. The puncture released the contents of the aerosol including the isobutane propellant and the ethanol solvent, both of which are highly flammable. A propane-fired hot water heater was inside the bathroom and the pilot light ignited the flammable propellant and solvent from the hairspray, causing severe burns to the woman. While in recovery from her burns, the woman suffered a stroke. The aerosol hairspray was manufactured in an aluminum monobloc aerosol container. The issues in the case addressed by Chemaxx were the impact/puncture resistance of the aluminum monobloc aerosol container and its advantages/disadvantages compared to three-piece steel aerosol containers. The methods employed by Chemaxx included simulated drop-impact tests, mechanical strength tests, hardness testing, scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDAX).

Under Sink Scenario

It was a late summer day and a woman and her friend were in the kitchen baking pies when There was a popping sound under the sink. One of the women opened the cabinet door and noticed an aerosol can of insecticide on its side. Just as she went to pick up the can a flash explosion occurred. The aerosol can was on the order of ten years old and had corroded around the bottom double seam (see photo) to the point of failure. The flash explosion was caused by the flammable propane and butane propellants when they reached the burning flames in the gas oven. The woman received severe burns to her legs and her dog also caught on fire.



Bottom of Can



Top of Can

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