AIRCRAFT CARGO FIRE SUPPRESSION USING LOW PRESSURE DUAL FLUID WATER MIST AND HYPOXIC AIR

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ABSTRACT

Water mist is gaining acceptance as a substitute for gaseous fire suppression agents worldwide. In commercial aircraft applications the FAA/CAA have adopted a Minimum Performance Standard (MPS) [1] testing protocol for alternative fire suppression agents based on the level of safety obtained from full scale experiments using HALON 1301. This paper will discuss the full scale testing and experiments used to research design a novel system that exceeds the MPS using low pressure dual fluid (LPDF) water mist and FirePASS Hypoxic Air.

Using available or existing resources on commercial aircraft for fire protection is a novel concept. A new effective fire suppression technology that will not add weight or add new systems to maintain is attractive to operators of an already cash strapped airline industry. Aircraft system designers have always remained within their professional or assigned discipline when working on new designs. Fire suppression, propulsion, environmental control, interior design engineers have always met their individual requirements. Interactions between sub systems has only been interfaced in the overall aircraft requirements of weight, volume and the impact of overall aircraft performance specifications, i.e.: range, fuel consumption and passenger comfort. Integration of these individual systems in the past has only been from a fire and safety standpoint to meet the Federal Aviation Regulations (FAR) requirements.

INTRODUCTION

Using available or existing resources, such as potable water and or air conditioning for a suppression system is a relatively new concept. In the past when a fire safety issue was identified a purpose built suppression system was mandated to mitigate the individual threat. Aircraft lavatory trash containers and detection and suppression systems in cargo compartments have been installed in the last ten years. With the new security and international threats to commercial aircraft, a more cost effective and versatile system is required.

Using water as an agent that will meet the FAA/CAA Minimum Performance Standard (MPS) requirements has been a difficult task. Aircraft cargo compartments, vary in volume and fuel loads. They can also vary for empty to fully loaded based on individual operator requirements. Projected fire scenarios were developed by the FAA's William J. Hughes Technical Center with the International Aircraft Systems Fire Protection Working Group. Fuel loading, repeatability and suppression difficulty were all considered, along with reflection of fires that had or could be seen in cargo compartments of commercial aircraft in the past. These consist of a Class B surface load, a bulkload deep seated class A and a containerized deep-seated class A fires. In addition, an exploding aerosol can scenario was designed and proved the hardest of the scenarios to mitigate.

In 1998 the FAA review the passenger deaths in commercial aircraft and determined that over 80% died from inhalation of toxic post combustion byproducts of the interior components. This led to changing the flammability rules airworthiness standards in part IV of appendix F of FAR 25.853, for transport-category aircraft with passenger capacity of 20 or more seats certified for occupation during takeoff, taxi and landing.. The IAI fire protection laboratory started looking at methods to further mitigate the combustion byproducts in the cabin atmosphere. That led to a full scale live fire test on a aircraft in 1999 under the sponsorship of the US NAVY Naval Air Systems Command and with the Naval Research Laboratory (NRL) [6].

Full-scale fire testing, based on the Federal Aviation Administration, Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems (MPS) [1]. Using previously tested and base lined, deep seated combustible fires, bulk-load fires, containerized fires, surface burning, flammable liquid fires, aerosol can explosion were tested. The tests were conducted between June and November 2004 in a 2000 +- 100 CuFt (56.6 +- 2.8 Cubic Meter) device designed to replicate the cargo bay of a wide body airliner. The device conforms to the requirements of the MPS in volume and instrumentation. Tests were part of a continuing long term research program at International Aero Inc.'s, Fire Suppression Laboratory, based on ongoing ground and flight testing started 1998. On April 1,2004 International Aero Inc, formed International Aero Technologies LLC to continue this research.

Agent

Low Pressure Dual Fluid (LPDF) Water Mist as a total flooding agent is very effective in controlling or extinguishing most fires. The unique nozzle was patented by the NAVAIR in 1996. Originally developed to replace HALON1301 in F-18 Hornet engine nacelle, the LPDF nozzle produces 50 micron diameter water droplets at pressures from around 0.80 to 15 bar.

The nozzle is also capable of adjustable flow rates by changes in both fluid inlet pressures. This is a unique property of the design. The operating pressure and associated flows can be varied while operating without changing the droplet diameter. The nozzle has very large orifices and is not prone to clogging like conventional hydraulic mist nozzles. The gas and liquid pressures are equal. In a normal flooding situations the water mist alone will penetrate the flame front, absorb the heat and control the fire.

Test device

The test device was constructed from steel plate and angle iron (Fig 1a) to replicate the FAA MPS device (fig 1b. The device was instrumented IAW Ref 1 and with the addition of three video camera positions and six oxygen sensors. The device was fitted with a remote video and data server allowing live viewing of experiments over the internet via secure data and video feed. This allowed live fire demonstrations and test fires to be observed by the both FAA and NTSB.

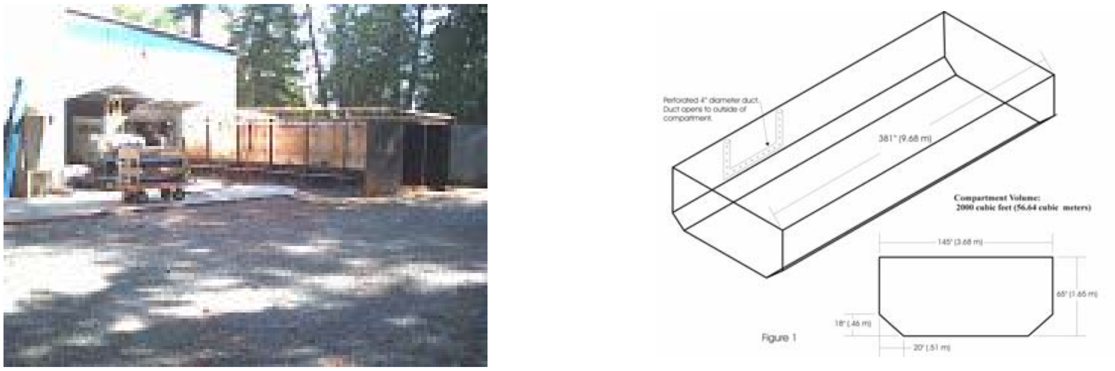


Figure 1a Test Article, 1b. dimensional drawing

The Low Pressure Dual Fluid (LPDF) water mist and Hypoxic Air are fed from a central location via plastic pipe manifolds. These pipes were constructed from PVC and ABS plastics to show the use of inexpensive light weight materials. Air was passed through a duct manufactured from 2.0 inch (50mm) PVC pipe to a standard passenger services unit feed 0.75 inch (19mm) fabric flex hose to the nozzle. Water was fed from a Boeing 727 potable water tank via 0.50 inch (12.7mm) ABS hose. At the mist nozzle the water is supplied by a 0.125 inch (6.2mm) ABS piercing adapter. The manifolds were split with “Tees” into four segments. Each segment can be operated individually. Valves allow operation of one or more of the four manifold sections for a single test. Water and air into the device are manually operated independently by the test supervisor or principle investigator. The System pressure, airflow is monitored to replicate the bleed air from commercial airliner Auxiliary Power Unit (APU) or engine bleed air via the environmental control air conditioning packs.

Plant compressed air was supplied with a Shulair Compressor and passed through Air Liquide, MEDAL^{TM} hollow fiber membranes (Fig2). These are a type used in the offshore oil and gas industry. A reverse osmosis permeable membrane system. This type is more efficient and we chose the design because of high volume flow rates. These membranes separate gases by the principle of selective permeation across the membrane wall. For polymeric membranes, the rate of permeation of each gas is determined by its solubility in the membrane material, and the rate of diffusion through the molecular free volume in the membrane wall. Gases that exhibit high solubility in the membrane, and gases that are small in molecular size, permeate faster than larger, less soluble gases. These reduce the oxygen in the air to the test device. The purity of the desired gas stream can be adjusted by changing the operating conditions. After passing the MEDAL^{TM} canisters the air is passed to the air side of the air distribution manifold using 1.0 inch (25mm) flex hose.

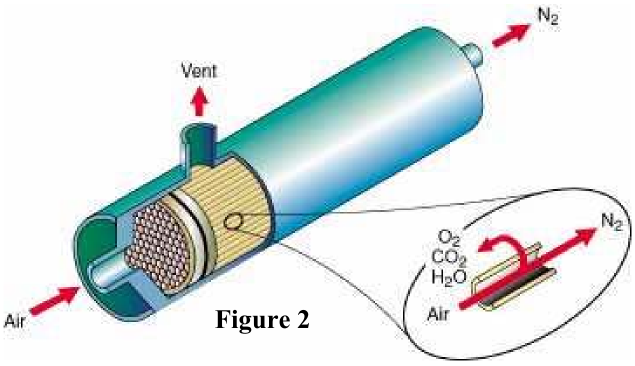


Figure 2

Inlet and outlet pressures were adjusted to replicate the aircraft environmental system pressures into the test device. Maxtec medical oxygen sensors were used to monitor the air oxygen content. These are a fuel cell type of monitor and oxygen content is chemically converted to a voltage based on saturated oxygen concentration. These proved to be a robust sensor to this application. Air samples were drawn from the test device in six locations via common vacuum manifold. Samples were drawn through 3/8” copper tubing, through a one-micron water separator filter and then passed by the sensor and into the manifold. Sampling was taken at equally spaced and offset locations every four feet, in the sidewall 27 inches off the floor of the test article. A single sensor was places in the air side inlet duct prior to the Tee. Pressure was monitored at the same location using an Omega PX series pressure transducer and a visual analog gage.

Test Protocol

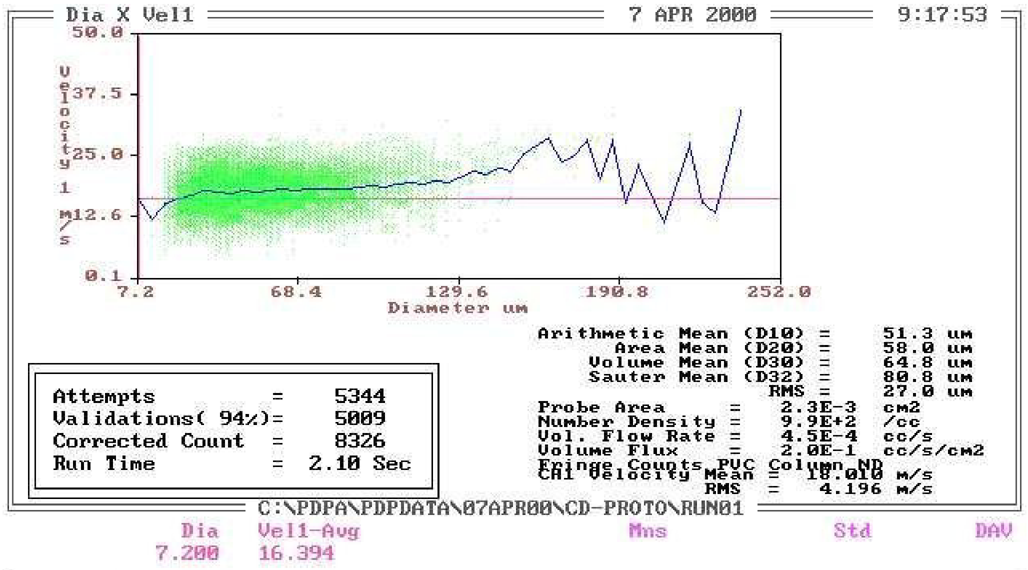
After construction of the test article, an instrument calibration and device characterization test series was initiated. The preliminary testing was completed using small scale fires and tell tail cups to measure agent distribution. After establishing optimum misting flow rates and repeatable class B fires out times, the FAA scenario fire loads were commenced. Starting with a partial loading of class A bulkload fuels the system was run with normal atmospheric oxygen concentrations. A device leakage rate of fifty cubic feet a minute (50 cfm 1.42 $M^{3/}M$) is maintained by a internal manifold designed to simulate a leaking cargo door seal in-flight. Gas pressure and water manifold pressure were set at 3 psi (0.21 Bar) this provided full control and often extinguishment of the fires to the FAA alternative MPS requirement. Since Halon 1301 and other alternative gasses tested were not effective in extinguishment of the deep seated fires, the FAA MPS is a suppression only test, not an extinguishment protocol. Pass fail criteria is based on a maximum device temperature recorded and an accumulated time/temperature value. All tests Initiation times and temperatures were FAA MPS tolerances.

A computer automated virtual test instrument was written for the protocol. This custom test instrument monitored the oxygen levels; internal temperatures, fluids flow rate, pressures and device status along with pass fail criteria using the FAA MPS perimeters. This allowed the test supervisor to monitor camera feeds and maintain pad safety and quickly scan instrument and device status.

In the FAA MPS the Exploding Aerosol Can provided a unique challenge. The water mist alone suppressed and completely extinguished the class A and B fires, excluding the aerosol can explosion. Introduction of a stoichiometric mixture into an ignition source with out a chemical mechanism to inert the atmosphere seemed impossible. However, FirePASS Hypoxic Air introduced with the mist was the elusive solution industry had been seeking for several years. Hypoxic Air is a USEPA SNAP listed agent of reduced oxygen concentration atmosphere. This agent was obtained by passing compressed air through a reverse osmosis membrane. The Hypoxic Air has two functions as the second part of the dual fluid system used to propel the water and two as a reducer of the oxygen levels.

Low Pressure Dual Fluid Water Mist Nozzle

US U.S. Patent No: 5520331   Issue Date: May 28, 1996. was license for this application to International Aero Inc. (FAA repair station IQNR108K). Mist data below was collected at 5 PSI (0.34 Bar) for both liquid and gas.



```
Dia X Vel1                    7 APR 2000            9:17:53

              Arithmetic Mean (D10) =     51.3 um
                    Area Mean (D20) =     58.0 um
                  Volume Mean (D30) =     64.8 um
                  Sauter Mean (D32) =     80.8 um
                                RMS =     27.0 um
              Probe Area        =   2.3E-3   cm2
              Number Density    =   9.9E+2   /cc
              Vol. Flow Rate    =   4.5E-4   cc/s
              Volume Flux       =   2.0E-1   cc/s/cm2
              Fringe Counts PVC Column ND
              CH1 Velocity Mean =   18.010 m/s
                           RMS  =    4.196 m/s

Attempts           =    5344
Validations( 94%)=      5009
Corrected Count    =    8326
Run Time           =  2.10 Sec

C:\PDPA\PDPDATA\07APR00\CD-PROTO\RUN01
     Dia     Vel1-Avg            Mns            Std          DAV
   7.200       16.394
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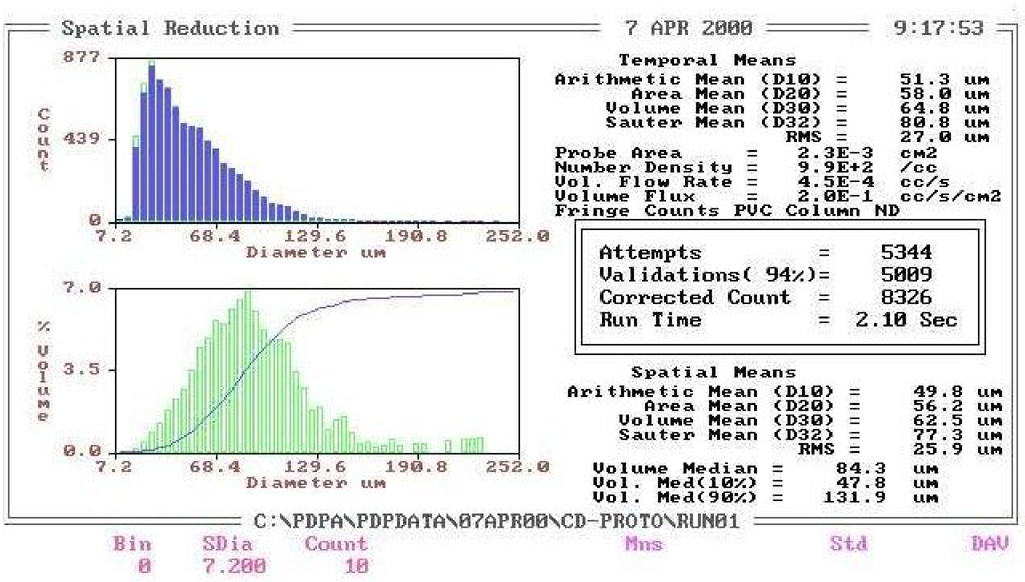
Figure 3 Mean aerodynamic diameter data



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Spatial Reduction             7 APR 2000            9:17:53

                    Temporal Means
              Arithmetic Mean (D10) =     51.3 um
                    Area Mean (D20) =     58.0 um
                  Volume Mean (D30) =     64.8 um
                  Sauter Mean (D32) =     80.8 um
                                RMS =     27.0 um
              Probe Area        =   2.3E-3   cm2
              Number Density    =   9.9E+2   /cc
              Vol. Flow Rate    =   4.5E-4   cc/s
              Volume Flux       =   2.0E-1   cc/s/cm2
              Fringe Counts PVC Column ND

                Attempts           =    5344
                Validations( 94%)=      5009
                Corrected Count    =    8326
                Run Time           =  2.10 Sec

                     Spatial Means
               Arithmetic Mean (D10) =     49.8 um
                     Area Mean (D20) =     56.2 um
                   Volume Mean (D30) =     62.5 um
                   Sauter Mean (D32) =     77.3 um
                                 RMS =     25.9 um
                 Volume Median =     84.3   um
                 Vol. Med(10%) =     47.8   um
                 Vol. Med(90%) =    131.9   um

C:\PDPA\PDPDATA\07APR00\CD-PROTO\RUN01
   Bin    SDia     Count          Mns            Std          DAV
     0    7.200       10
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Figure 4 Droplet density

FAA Minimum Performance Testing Protocol

Four separate fire scenarios were used based on the FAA cargo MPS. The test were:

BULK LOAD FIRE

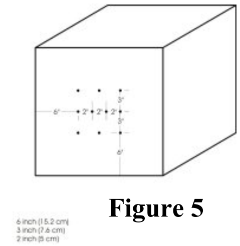


Figure 5

The fire load is described in detail in the MPS for this scenario and consists of 178 single-wall corrugated cardboard boxes, with nominal dimensions of 18 x 18 x 18 inches (45.7 x 45.7 x 45.7 cm). The weight per unit area of the cardboard is 0.11 lbs/ft2 (0.5417 kg/m2). The boxes are filled with 2.5 pounds (1.1 kg) of shredded office paper, loosely packed without compacting. The standard weight office paper is shredded into strips, not confetti. The weight of a filled box is 4.5 ± 0.4 lbs. (2.0 ± 0.2 kg). The boxes are conditioned to room standard conditions. The flaps of the boxes are tucked under each other without using staples or tape. The boxes are stacked in two layers in the cargo compartment in a quantity representing 30% of the cargo compartment empty volume.

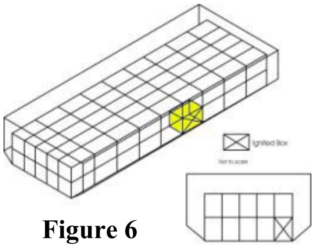
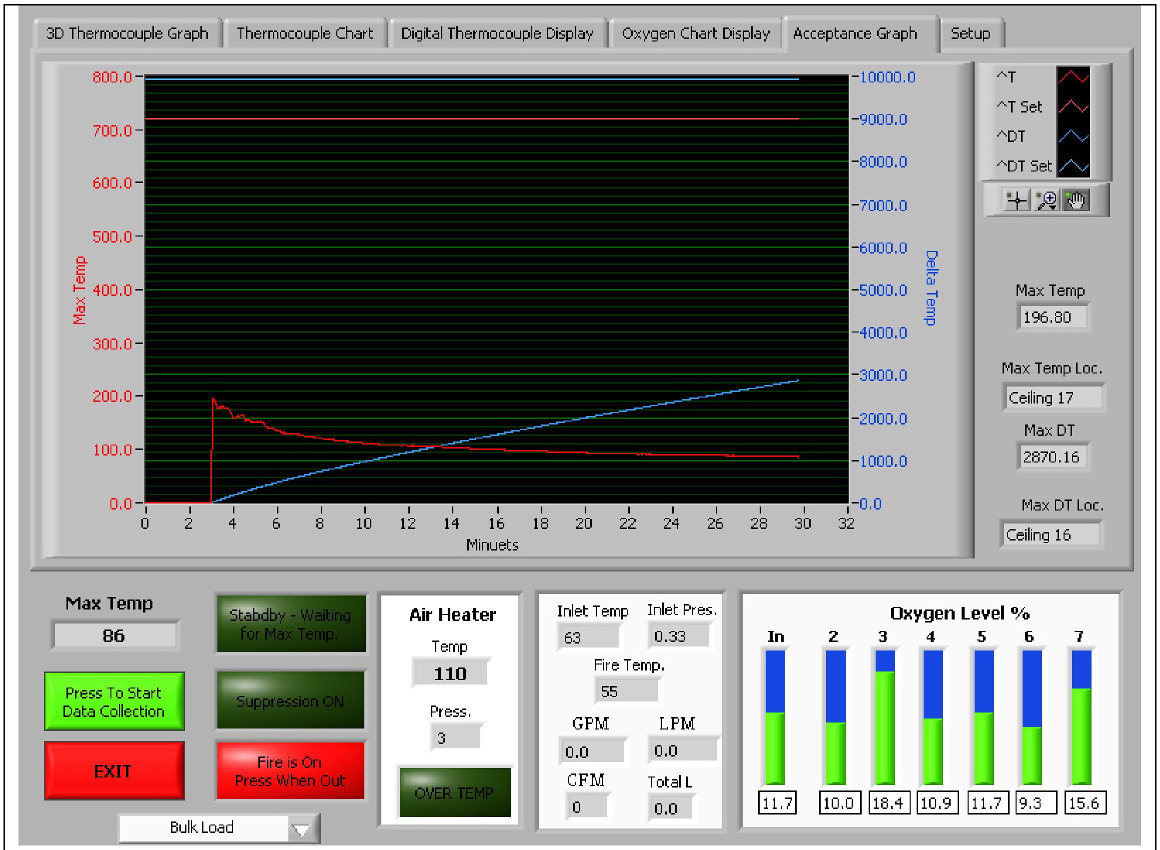


Figure 6

The boxes are placed in the test device container and prepared for the test. The electrical igniter box was prepared and tested for electrical continuity. The safety check list was reviewed and instrument verified. 12.5-13.5 amperes of 115v electrical power we applied to the NiChrome wire. Smoke was observed with in 15 seconds and open flames in less than 60 seconds. When the first ceiling thermocouple temperature reaches 200 Deg f the data collection systems is started. One minute after the ceiling temperature reached 200 Deg F the air and water are applied through as manual valve system. LPDF misters operation is verified by video cameras and audible indication. One minute after agent introduction, the time over temperature and maximum thermocouple values are recorded for 28 minutes.

After the third test, the boxes were taped closed. It was found the folded flaps caused water to collect on the upper surface of each box and drip into to the inside of the box and the one below. This caused the shredded paper to become damp, possibly reducing the fuel load. The first series were run with air and water. Additional tests were conducted with water additives to evaluate the fire out time and increased absorption of the water into the paper. No definitive fire out data was attained with the additives, although they might prove useful in hidden fires or in class B spill fires located in non-accessible areas.



Max Temp: 196.80

Max Temp Loc.: Ceiling 17

Max DT: 2870.16

Max DT Loc.: Ceiling 16

Max Temp: 86

Air Heater

Temp: 110

Press.: 3

Inlet Temp: 63

Inlet Pres.: 0.33

Fire Temp.: 55

GPM: 0.0

LPM: 0.0

CFM: 0

Total L: 0.0

Oxygen Level %

In	2	3	4	5	6	7
11.7	10.0	18.4	10.9	11.7	9.3	15.6

On the data screen above as long as the red and blue lines do not exceed the matching straight lines at the top the test passes the FAA MPS.

The screens below are the temperature plots of the device and oxygen concentrations of the test article

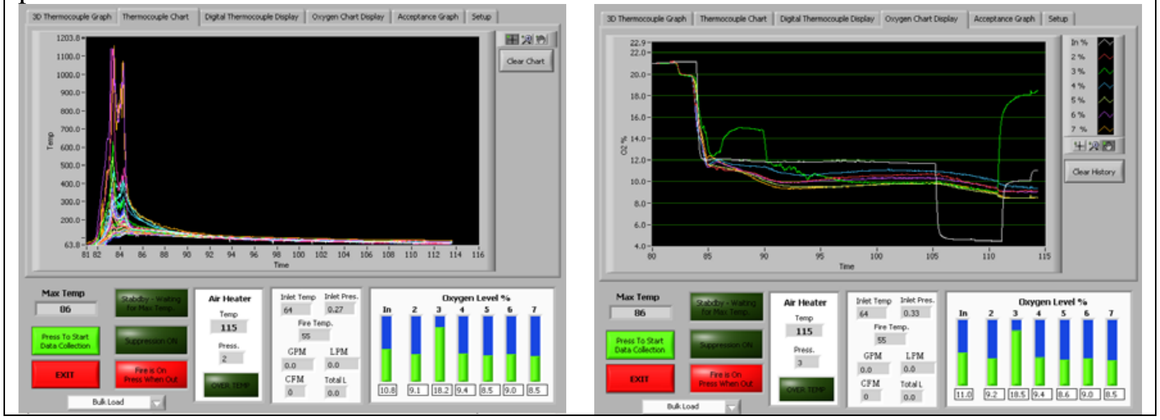


Figure 7 Bulk load instrument

CONTAINERIZED LOAD FIRE

The fire load is described in detail in the MPS for this scenario and the same type of paper-filled cardboard boxes and the same type of igniter as used in the bulk load fire scenario are used (Fig 5). The boxes are stacked inside a LD-3 container as shown in figure 4. The container is closed with two 12" (304.8MM) by 4" (106.0MM) slots located in one side and under the edge of the angled side. All

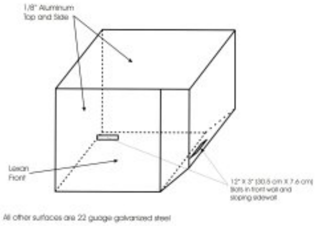


Figure 8

combustion air and agent must enter the device via these openings. The fire is located inside the container, and the ceiling and wall thermocouple temperature of the device are monitored like the other fire scenarios. When the ceiling thermocouples measure 200F, the timer is started similar to the bulk load. After one minute, the agent is applied to flood the entire test device.

The containerized fire is similar to the bulk load. The igniter box is prepared and placed inside the LD3 container. The remaining boxes are placed inside the LD3 closed and positioned (Fig 9). The power is applied and the status is monitored by remote camera. The Small lower slot is observed along with three extra thermocouples inside the upper level of the container above the boxes. Fires develop very readily inside the container since the air intake to the container is located directly in front of the ignition box. Internal LD3 temperatures exceeded 750F for several minutes before the device ceiling thermocouple attain the required 200F. After the start time delay the water mist was applied, temperature in the large enclosure dropped to around 150 F while the internal temperature of the LD3 cargo container remained high for several minutes. Then as the air water mist was entrained through the entry slot the fires in the LD3 was first controlled then extinguished. Damage to the boxes in the LD3 was relatively low when compared to the fire damage in the bulk load scenario. This is attributed to rapid reduction of the O_2 by the initial fire, small slot for replacement atmospheric gases and the introduction of water mist with the make up air.

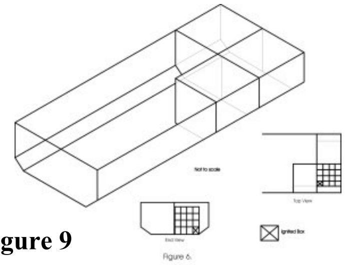
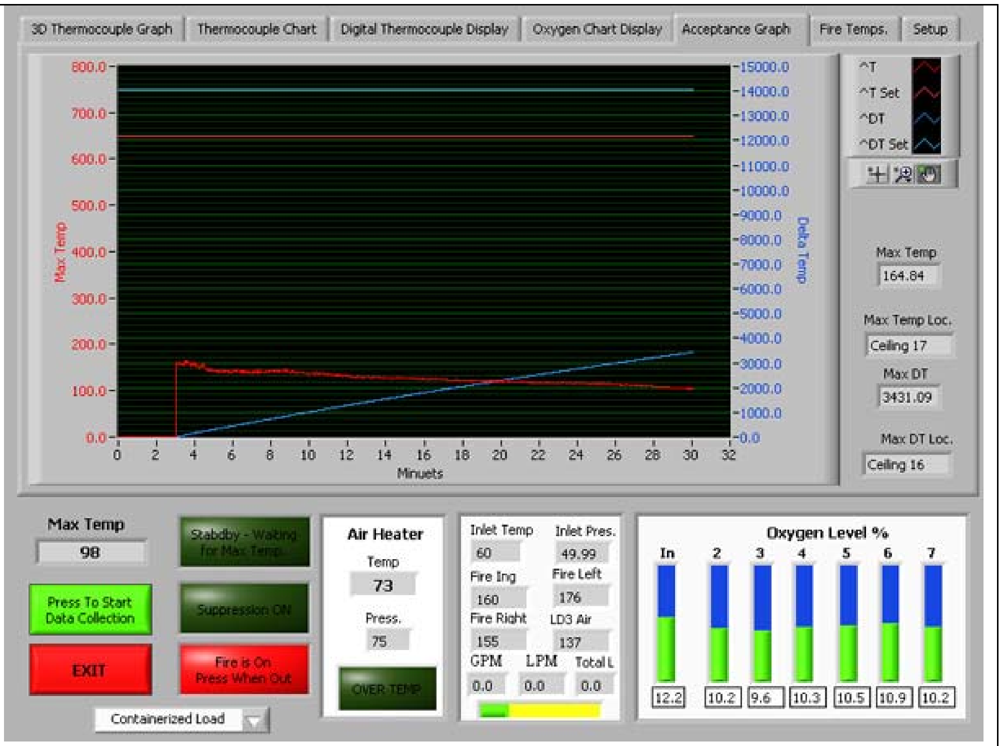


Figure 9



Max Temp 164.84
Max Temp Loc. Ceiling 17
Max DT 3431.09
Max DT Loc. Ceiling 16

Max Temp 98

Containerized Load

Air Heater
Temp 73
Press. 75

Inlet Temp 60
Inlet Pres. 49.99
Fire Ing 160
Fire Left 176
Fire Right 155
LD3 Air 137
GPM 0.0
LPM 0.0
Total L 0.0

Oxygen Level %

In	2	3	4	5	6	7
12.2	10.2	9.6	10.3	10.5	10.9	10.2

On the data screen above as long as the red and blue lines do not exceed the matching straight lines at the top the test

The screens below are the temperature plots of the device and oxygen concentrations of the test article passes the FAA MPS.

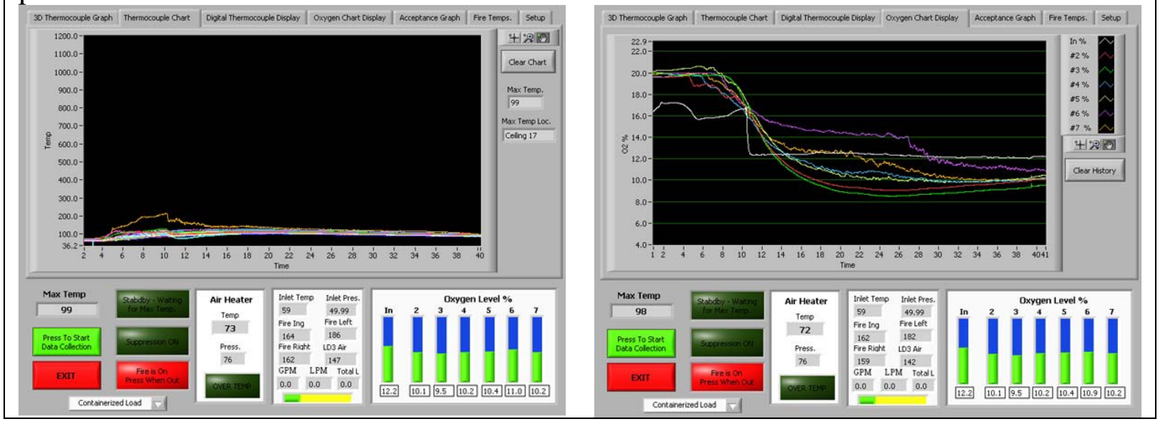


Figure 10 Containerized Load Instrument

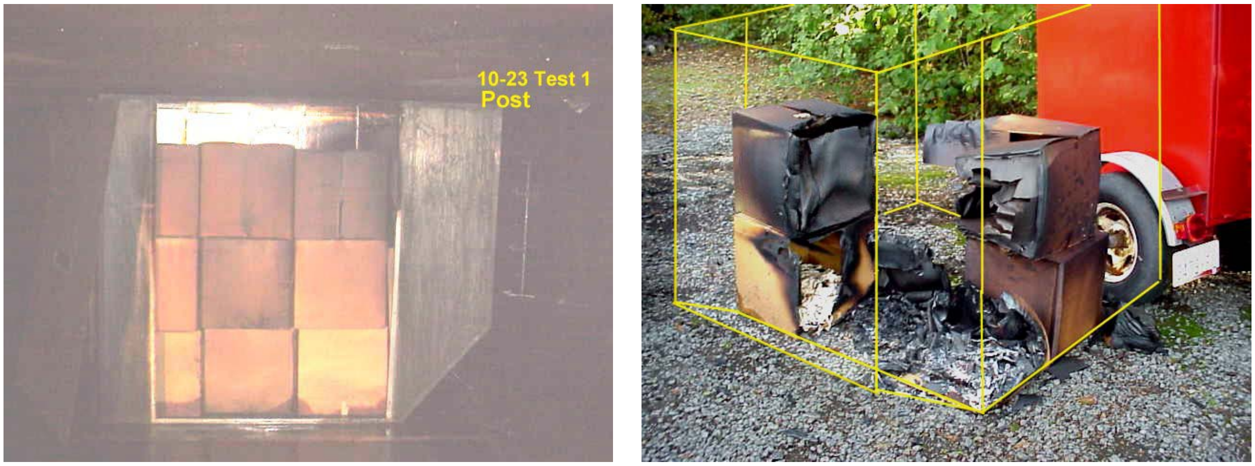


Figure 11 a. Post Fire damage to the containerized fire load b. Damaged boxed reconstructed

Surface Fire

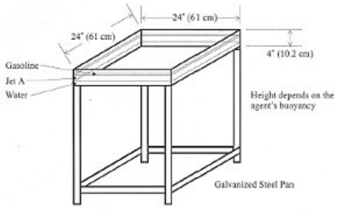
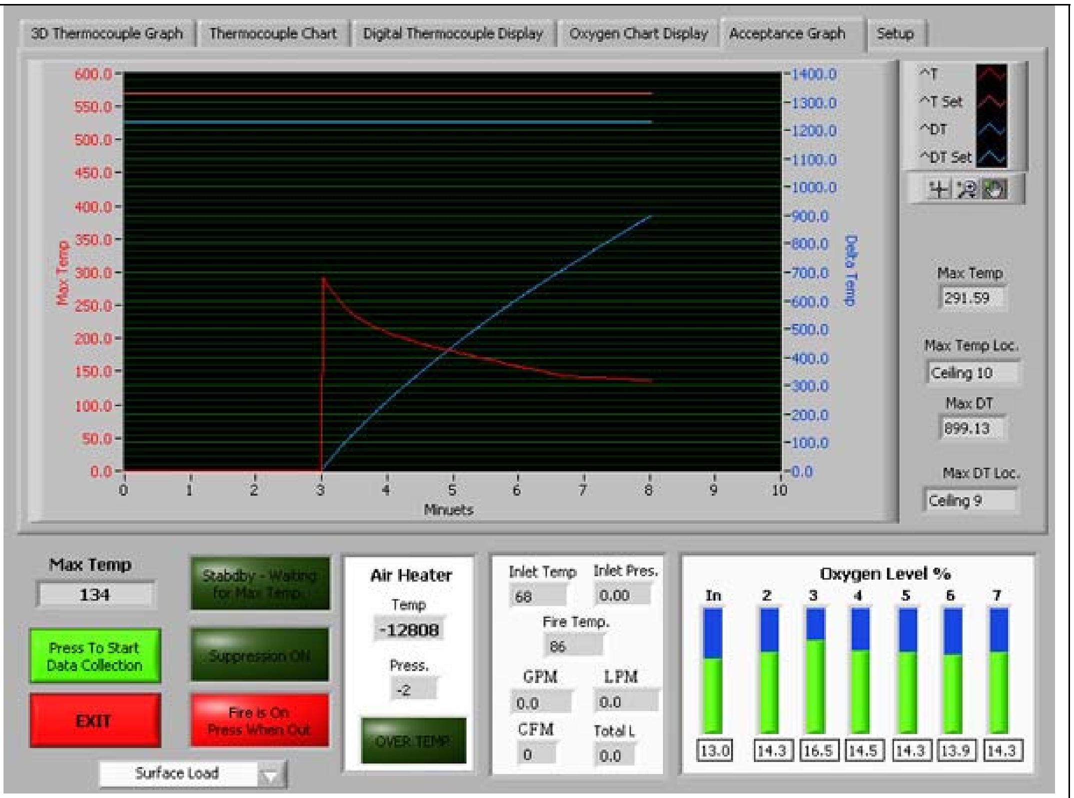


Figure 12

The surface fire load is described in detail in the MPS for this scenario. One-half U.S. gallon (1.9 liters) of Jet A fuel in a square pans is used for this scenario. The pan is constructed of 1/8-inch (0.3-cm) steel and measures 2' by 2' by 4". high (60.9 x 60.9 x 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 cool and minimize warping. This quantity of fuel and pan size is sufficient to burn vigorously for approximately 4 minutes if not suppressed. The pan should be positioned in the cargo compartment in the most difficult location for the particular suppression system being tested and in accordance with the directions in the MPS. After manual ignition of the fuel pan the time was started shortly after securing the exit door. After the prescribed one minute delay after attaining 200 Deg F, the mist is applied to the test apparatus. Several Class B fuels were tested in addition to Jet A required by the FAA Cargo MPS, gasoline, heptane, methyl ethyl ketone, methanol, and mixtures of these were burned. Flame out time with Jet A became repeatable to the point of calling flame out time with the clock. Maximum ceiling temperature and time over temperature profiles remained within the Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems



Max Temp 291.59

Max Temp Loc. Ceiling 10

Max DT 899.13

Max DT Loc. Ceiling 9

Max Temp 134

Air Heater Temp -12808 Press. -2

Inlet Temp 68 Inlet Pres. 0.00

Fire Temp. 86

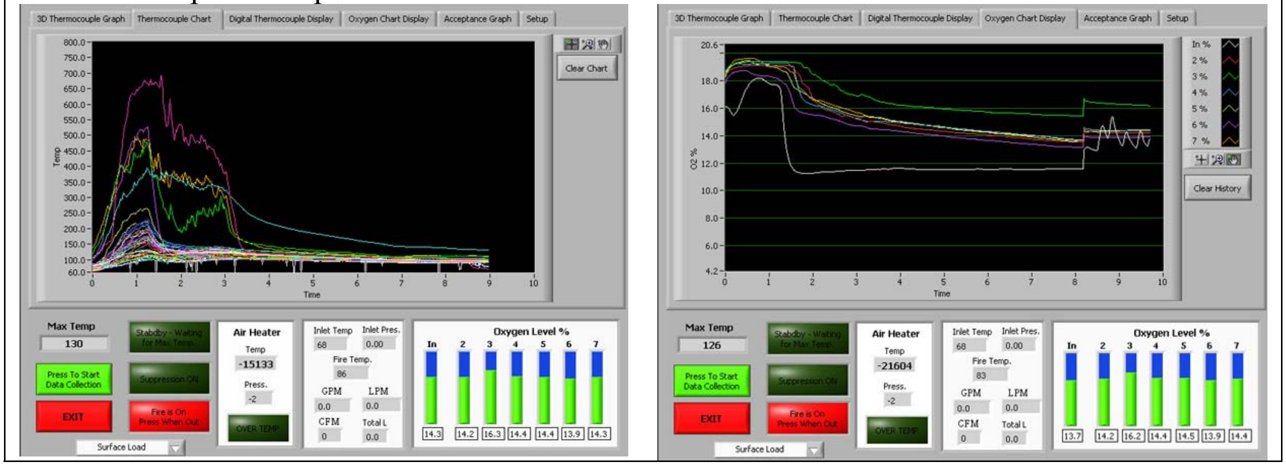
GPM 0.0 LPM 0.0

CFM 0 Total L 0.0

Oxygen Level %	In	2	3	4	5	6	7
	13.0	14.3	16.5	14.5	14.3	13.9	14.3

On the data screen above as long as the red and blue lines do not exceed the matching straight lines at the top the test passes the FAA MPS.

the screens below are the temperature plots of the device and oxygen concentrations of the test article



Max Temp 130

Air Heater Temp -15133 Press. -2

Inlet Temp 68 Inlet Pres. 0.00

Fire Temp. 86

GPM 0.0 LPM 0.0

CFM 0 Total L 0.0

Oxygen Level %	In	2	3	4	5	6	7
	14.3	14.2	16.3	14.4	14.4	13.9	14.3

Max Temp 126

Air Heater Temp -21604 Press. -2

Inlet Temp 68 Inlet Pres. 0.00

Fire Temp. 83

GPM 0.0 LPM 0.0

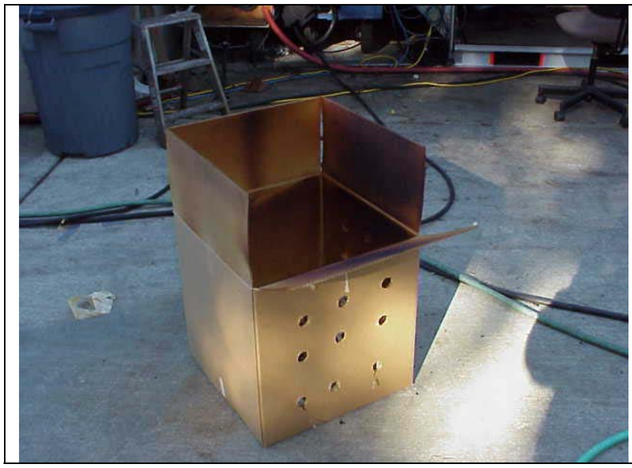
CFM 0 Total L 0.0

Oxygen Level %	In	2	3	4	5	6	7
	13.7	14.2	16.2	14.4	14.5	13.9	14.4

Figure 13 Surface load instrument screens

FirePASS Hypoxic air, *preventive mode*

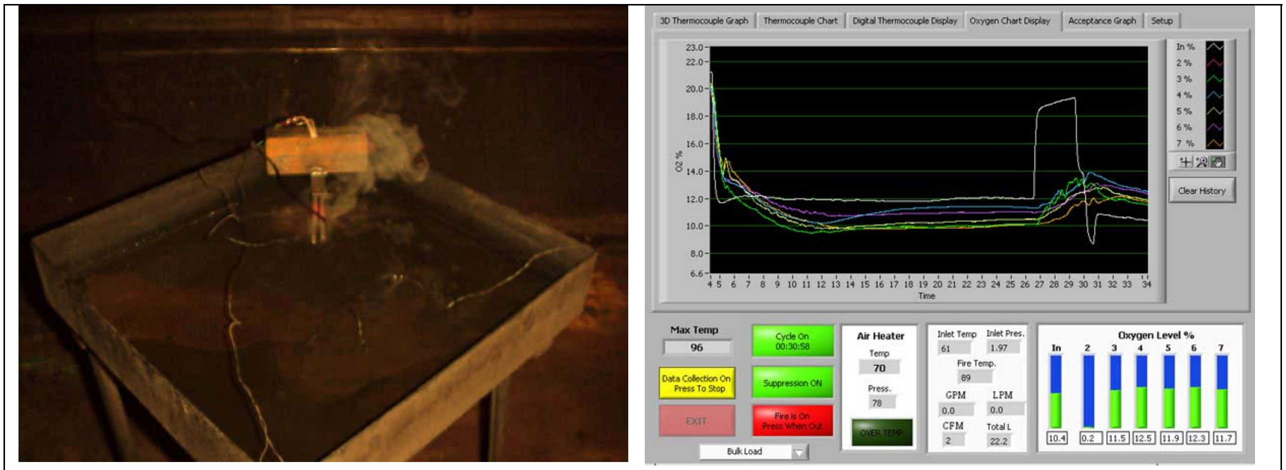
Testing revealed that if the FirePASS hypoxic air is introduced into the MPS device for a short time prior to the ignition source, the fires could be prevented entirely. Starting around 14% local oxygen concentrations the hot wire igniter could be energized with the normal 12.8~13.5 amps of 115Vac for in excess of four hours without flames or excessive damage to the cardboard box containing the ignition source and fuel load. In addition to the deep seated class A bulk load ignition box. Several of these test were repeated successfully. Starting with 45 minutes, then to 180, then 217 minutes for existing extended over ETOPS and 257 proposed ETOPS +30 min. All of these test were basically the same. Thermal damage to the shredded paper and card box was limited to areas surrounding the hot wire. The head damage was attributable for the electrical energy dissipated by the ni-chrome.



This shows the damage after 180 minutes. It 120 minutes video observations showed occasional sparks falling from the bottom of the box. Later inspection revealed the hot wire had burned through the bottom of the container. Fire brands The FirePASS preventive mode at 15 Percent oxygen concentration was capable of preventing flames. Smoke density was sufficient to alarm on the type of detectors used in commercial aircraft..

Figure 14 Class A fire load in hypoxic test

The surface pan Class B was tested with N-heptain, isopropyl alcohol, methyl ethyl ketone and a 1800 Deg F electrically heated probe immersed in the fuel without ignition. (Fig 15) This preventive mode has shown to not only be a viable alternative to Halon but also provided a superior level of safety over HALON 1301 systems in service today. Note: Explosive vapor buildup inside the container remains after securing the experiment. If the doors are opened too rapidly before the device cools down, with the inrush of fresh air a dangerous atmosphere may exists.



Max Temp 96
Cycle On 00:30:58
Air Heater Temp 70
Press. 78
Inlet Temp 61
Inlet Pres. 1.97
Fire Temp. 89
GPM 0.0
LPM 0.0
CFM 2
Total L 22.2

Oxygen Level %

In	2	3	4	5	6	7
10.4	0.2	11.5	12.5	11.9	12.3	11.7

Above shows the hot rod immersed in class B fuel (N-heptain), vapor can be seen rising from the fuel pan. No flames were observed for 25 minutes. Oxygen plot on the lower right shows internal apparatus O_2 levels. The spike at 24 - 30 minutes is venting the airside with out the MEDAL^{TM} membranes. When it was realized the atmosphere in the apparatus was close to explosive, (due to evaporated n-heptain) the MEDAL were brought back on line for safety..

Figure 15 FirePASS Preventive mode and Class B fuels

Further, it is possible that the same Onboard Inert Gas Generating System (OBIGGS) can also be used for the cargo compartment. The FAA will soon mandate using polymeric membranes to provide nitrogen for fuel tank inserting. Since the ullage in the wing tanks is at its smallest level prior to push back from the gate, the volume of NEA needed to inert the tank is not extreme. After the tank ullage has been processed, the airflow can be diverted to the cargo compartment system to achieve the above-mentioned benefit. OBIGGS using engine or Auxiliary Power Unit APU can produce large quantities of Hypoxic Air. The output volumes on the ground are more that sufficient to inert the fuel tanks and treat the Cargo compartment without any determent to either aircraft zone.

If sized correctly, OBIGGS can be an integrated design with a "systems approach" for fire protection in commercial aircraft. The system can provide wing tank inerting, fire protection for Cargo Bays, hidden or non-accessible areas. The system can be designed with a minimum of additional cost and weight. A low pressure OBIGGS system does not need stainless or metal plumbing. The LPDF mister can provide normal airflow and be modulated with valves into the area requiring fire mitigation or prevention.

Future Work

The integration of the fuel tank OBIGGS and the Low Pressure Dual Fluid water mist in to a viable commercialized suppression system for cargo bays. Development on an integrated aircraft wide system with flight-testing and of a better method to verify suppression efficiencies of water mist. Since the amount of FirePASS hypoxic air is only limited to the amount of fuel available to the engine or APU, this is the first viable and true gate to gate fire suppression system.

Recommendations

The future safety of the flying public from fire is an ever-increasing task. The commercial airline industry is faced with growth along with an escalating threat. Operating cost and fuel prices continues to strain a cash strapped industry. Extra systems to detect and suppress fires are expensive and add additional weight to airliners. Using existing systems and available resources to mitigate the emerging threats only makes sense. The potable water and air conditioning systems are available and the OBIGGS will be mandated for fuel tank inerting. If these available resources are used in a systems approach, we can prevent the fires instead of suppressing them. The FirePASS preventive mode will prevent most fires. However, if one should develop, the LPDF water mist combined with the hypoxic air will extinguish it providing for total protection with no weight gain and no additional maintenance. This is a win-win solution for the airline industry. LPDF mist and Hypoxic air answers the MPS for both cargo bays and fuel tanks and with little additional modifications could be installed everywhere for additional protection inside the aircraft cabin.

Conclusions

Data collected using LPDF and Hypoxic air exceed the minimum performance required by the FAA.

Bulk Load Fire scenario

The acceptance criteria for the bulk load fire scenario is that none of the ceiling or sidewall thermocouples shall exceed 720°F (382°C) starting 2 minutes after the suppression system is initially activated until the end of the test. In addition, the area under the time-temperature curve of each thermocouple in the compartment shall not exceed 9,940°F-min (5,504°C-min). The area should be computed from 2 minutes after the time of initial suppression system activation until the end of the test (28 minutes later).

MPS Value	*FAA MPS max temp baseline of 720°F (382°C)*	*Improvement over the FAA HALON 1301 baseline MPS in %*	*Time X temp baseline MPS 9,940°F-min (5,504°C-min*	*Improvement over the FAA HALON 1301 Time X temp baseline MPS in %*
Test one	*86.0* F	*88.0%*	*2870* F	*71.1%*
Test two	*92.4* F	*88.0%*	*3139* F	*68.5%*
Test three	*109.8* F	*84.7%*	*3837* F	*61.39%*
Test four	*78.4* F	*89.1%*	*2645* F	*73.3%*
Test Five	*88.7* F	*87.6%*	*3367* F	*66.12%*
Average (1-5)	**91.65 F**	**87.27%**	**3122 F**	**68.59%**

Containerized-load fire scenario

Data collected using LPDF and Hypoxic air exceed the minimum performance required by the FAA. The criteria for the containerized-load fire scenario is that none of the ceiling or sidewall thermocouples exceed 650°F (343°C), starting 2 minutes after the suppression system is initially activated until the end of the test. The area under the time-temperature curve cannot exceed 14,040°F-min (7,782°C- min).

MPS Value	*FAA MPS max baseline of* ***650°F (343°C)***	*Improvement over the FAA HALON 1301 baseline MPS in %*	*Time X temp baseline MPS 14,040°F-min (7,782°C-min)*	*Improvement over the FAA HALON 1301 baseline MPS in %*
Test one	*179* F	*72.4%*	*2545* F	*81.8%*
Test two	*122* F	*81.2%*	*3573* F	*74.5%*
Test three	*103* F	*85.1%*	*3431* F	*75.5%*
Test four	*127* F	*80.0%*	*3478* F	*75.2%*
Test five	*118* F	*81.8%*	*3256* F	*76.8%*
Average (1-5)	***129.8***	***80.%***	***3256***	***77.1%***

Surface-burning fire scenario

Data collected using LPDF and Hypoxic air exceed the minimum performance required by the FAA. The acceptance criteria for the surface-burning fire scenario is that none of the ceiling or sidewall temperatures exceed 570°F (299^{o}C) starting 2 minutes after the suppression system is initially activated until the end of the test. In addition, the area under the time-temperature curve cannot exceed 1230°F-min (665°C-min).

MPS Value	*FAA MPS max temp baseline of 570°F (299^{o}C)*	*Improvement over the FAA HALON 1301 baseline MPS in %*	*Time X temp baseline MPS 1230°F-min (665°C-min)*	*Improvement over the FAA HALON 1301 baseline MPS in %*
Test one	*250* F	56.1*%*	*918* F	*25.3%*
Test two	*146* F	74.3*%*	*709* F	*42.3%*
Test three	*189* F	66.8*%*	*344* F	*72.0%*
Test four	*190* F	*66.6%*	*344* F	*72.0%*
Test five	*142* F	*75.0%*	*592* F	*51.8%*
Test six	*119* F	*79.1%*	*270* F	*78.0%*
Average (1-6)	**172.6 F**	***69.7%***	***529.5* F**	**56.9%**

The future safety of the flying public from fire is an ever-increasing task. The commercial airline industry is faced with growth with an ever-increasing threat. Operating cost and fuel prices continues to strain a cash strapped industry. Extra systems to detect and suppress fires are expensive and add additional weight to airliners. Using existing systems and available resources to mitigate the emerging threats only makes sense. The potable water and air conditioning systems are available, the OBIGGS has been mandated for fuel tank inerting on al US carriers. If all these available resources are used in a systems approach, we can prevent the fires instead of suppressing them. The systems can be used in different aircraft zones to reduce the effects terrorist such as of fire in passenger cabins, non-accessible or hidden areas, fuel tank inerting. It may allow operators to extended flight times for post emergency landing allowing an aircraft diversion to a more suitable or safe airport. The FirePASS preventive mode will stop most fires, if a fire should arise, a zoned system with the water mist and hypoxic air can extinguish it. The system can be zoned to do all areas on the aircraft that have no protection at this time. Attics, non-accessible areas can be protected. MEDAL^{TM} membranes, can placed throughout the aircraft and normal air-conditioning can be diverted to provide fire protection when required.

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