CARGO FIRE PROTECTION SYSTEMS FOR FREIGHTER CONVERSIONS

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Abstract

Fire in the air is one of the most hazardous situations that a flight crew might be faced with. Fire may start in an engine or an APU, cargo holds, toilet waste bins, high temperature bleed air leaks, electrical equipment compartment or landing gear bays. Without an aggressive intervention, fire can lead to a catastrophe within a very short time (Figure 1).

Figure 1: FedEx MD-10 Memphis 19 Dec, 2003

Three key accidents: Saudi Arabian Airlines Flight 163 (1980), South African Airways Flight 295 (1987) and ValuJet Flight 592 (1996), led the Federal Aviation Authority (FAA) to revise the cargo fire protection regulations, in order to significantly improve flight safety. Among other requirements, the new regulation requires the use of smoke detection systems in cargo compartments to ensure early activation of firefighting procedures.

Israel Aerospace Industries (IAI) Bedek Aviation Group holds Supplemental Type Certificates (STCs) for conversion of passenger aircraft to Bedek Special Freighters (BDSF): B737-300 & -400, B747-100,-200 & -400, B767-200 with a 9g safety net and B767-300 with a 9g rigid barrier. Currently IAI Bedek is developing the B767-300BDSF with 9g net.

During the last decade, IAI Bedek Aviation Group, in collaboration with Siemens (France) Airborne Systems, developed state-of-the-art cargo smoke detection systems (SDS).

This paper describes smoke detection systems technology and implementation.

1 Introduction

Smoke sensing, the primary method of fire detection in cargo compartments, has evolved significantly during the past 50 years. While the basic principle of operation hasn't changed, new hardware (solid-state circuitry, microprocessors, better optics) and new processing algorithms have been introduced.

There are two basic designs of smoke detectors: ionization and photoelectric. Ionization detectors monitor ionized combustion byproducts as they pass through a charged electrical field. Photoelectric detectors measure light attenuation, reflection, refraction and absorption of certain wavelengths.

Ionization smoke detectors were used in early years, but this technology, for the most part, has been abandoned. A radioactive isotope charges the combustion products. However, everything else, including dust and fine water droplets, is also charged. Also, detectors' sensitivity changes with pressure and time, leading to increased false alarms. There is still a fair number of ionization detectors, found primarily on older models, in lavatories and some cargo bays that are almost always accessible areas where a fire alarm can be verified.

Photoelectric detectors have become the industry standard for smoke detection, primarily because ionization detectors were found to be unreliable. This is not to imply that photoelectric detectors are free from false alarms. Photoelectric detectors rely on scattered or reflected light, caused by particles between a light emitting source and a detection device. Based on experience, smoke detectors design has evolved, specifically to avoid false alarms and increase mean-time-between-failures (MTBF).

Solid-state circuitry made detectors sensitivity as a function of time and temperature, less prone to threshold drift, and thus, less prone to false alarming. Another advantage of solid state detectors is their much longer durability. Early models used low voltage light bulbs that had an extremely short life. Solid-state photoelectric detectors use a light emitting diode (LED) as its source of light.

Cargo smoke detection technology has not evolved to a level of performance equivalent to other fire protection systems. The key reason is cargo compartments environment, which varies greatly due to loosely packed cargo, enclosed containers (LD3), livestock, etc. Some compartments are cleaned periodically, while others remain dusty. Cargo compartments can be quite hot and humid and then at altitude, temperature drops below dew point, causing condensation. On the other hand, cargo compartments can be very cold. Cargo compartments environmental conditions variability is much greater than engine, or dry bays environment, therefore, designing a cargo bay smoke detection system is quite challenging.

Nevertheless, incremental improvements introduced over the years, enhanced performance. While other detection technologies have been considered, none have really been able to replace the optical technology. Densely packed or placed inside containers, cargo can allow a deeply seated fire, that emits very little heat or visible flame.

Smoke is the most consistent detectable parameter, although there are some exceptions, like closed-circuit TV and/or thermal detection. Open-air smoke detectors replaced ionization detectors and (unless absolutely necessary) duct detectors. Duct detectors use a vacuum source and lines routed throughout the cargo compartment. Ducted system reduces the number of detectors, since the ducts pick up air samples from around the cargo bay and transport them directly to the detectors. However, these ducts create a water condensation issue. Plus, they tend to pick up dust and other particles. Heaters and insulation were added to many duct systems to minimize water condensation.

Smarter detection logic, embedded in software algorithms, has improved processing and discrimination of smoke from non-smoke matter. While response time was reduced from five to just one minute in the late 1980's, there is little benefit in further reduction, but rather use the majority of the detection time to process air samples for fire byproducts, to reduce false alarming because of too little processing time.

Dual loop detection configuration, i.e. redundant output, is increasingly used. Like in engine fire protection systems, at least two detectors must sense smoke. Their signals are summed, before a fire alarm is issued. Improved dust screens and smoke sampling chambers have been developed. Temperature sensors are utilized in some smoke detectors. Thermal monitoring accommodates flaming combustion, such as with pressurized combustible aerosols.

Despite improvement, there are still many limitations. Since detectors rely on transfer of particles, their operational success depends highly on placement. Air flow rate and its dynamic characteristics are the important factors associated with smoke detection. Detector's location must permit combustion byproducts to reach it. If adequate coverage is not obtained, either air samples must be conveyed, or the smoke detector must be brought closer to the flow path of the hazard area. As outlined earlier, infrared (IR) thermal smoke detectors are a recommended supplemental supporting technology for cargo bays applications, and when installed in a dual loop configuration, better levels of performance and false alarm immunity can be achieved.

Another potential technology is laser detection. This technology offers increased sensitivity with better resolution and discrimination. Less than 0.1% obscuration levels (sensitivity measurement of light obstruction due to smoke in % per ft) are achievable. Plus, laser detectors offer an analog output, if trend information is of interest. However, these devises do not perform well in high vibration environments. For this reason, laser detection has not been introduced to cargo compartments. Also, it is impossible to count on a visual line-of-sight of cargo fire, therefore, cargo detection technologies cannot rely on the use of video camera or thermal imaging detection. Deep seated fires and/or fires inside containers will still be hidden. This reality makes thermal systems (alone) impractical. While other combustion products, such as CO/CO_2, could be monitored, these gases can origin from sources other than fire (livestock, plants, etc.). Plus, CO/CO_2 detectors are easily contaminated and have short life.

The presence of smoke is the most consistent parameter associated with a cargo fire. However, combination of smoke detection with other technologies may be used in the next-generation of cargo fire protection systems.

2 Lessons Learned from Cargo Fire Accidents

Cargo compartment fire is a rare event. The majority occur while the aircraft is on the ground, causing little or no damage or injury. Recurrent ignition sources include electrical, incendiary devices, oxygen canisters and exposure to heat sources within the cargo compartment including lighting, drain heaters, heat blankets and heat ducts or shrouds.

Cargo fire during flight is by far sparser than ground fire. Between 1976 and 1996, a key period of fire protection rulemaking and policy changes, there were 19 in-flight accidents/incidents involving Class C and Class D compartments (Figure 2). Based on the number of departures during this period, the event rate for in-flight cargo fire is approximately 0.085 per million departures, or one event for about every 12 million flights. Three of these events were fatal, resulting in 573 deaths, as summarized below:

- On August 19, 1980, a Saudi Airlines L1011, flight 163, took off from Riyadh, Saudi Arabia. Seven minutes after take-off, a warning indicated smoke in the aft Class D cargo compartment, specially equipped with a ventilation system and smoke detectors provided for animals transport. The flight engineer reported fire and smoke emanating from the extreme aft area of the passengers cabin, directly above the C-3 compartment. The captain decided to return to Riyadh. During the return flight, the flight attendants attempted to fight the fire, which had burned through the cabin floor, with handheld extinguishers. The aircraft landed some 20 minutes later, but instead of an emergency stop, the captain taxied off the runway to a taxiway. It was several minutes after stopping, before the engines were finally shut down. An evacuation was never initiated. All 301 passengers and crew perished.

- On November 28, 1987, South African Airways Flight 295 crashed into the Indian Ocean en route from Taipei to Mauritius, as a result of fire in the main deck cargo compartment. All 159 on board were lost. The crash occurred about ten hours into the flight, less than twenty minutes after smoke was reported. The airplane, a 747-200, configured as a Combi (main deck divided to passengers and cargo). No smoke detection system was installed in the Class B cargo compartments and controlling main deck fire on Combi airplanes relied on hand held fire extinguishers. Following this accident, the FAA and other authorities concluded that reliance on manual firefighting in large Class B cargo compartments was inadequate, and regulatory action was taken to require design and operational changes.

- On May 11, 1996, a ValuJet DC-9-32 Flight 592 crashed into the Florida Everglades approximately ten minutes after takeoff from Miami International Airport. The crash occurred while attempting to return to Miami and was the result of an uncontrolled fire in the forward Class D cargo compartment. The fire was attributed to improper transportation of chemical oxygen generators. The inadvertent activation of one or more of these generators provided an ignition source and contributed to the oxygen-fed fire which spread rapidly and ultimately rendered the airplane uncontrollable. All 105 passengers, two pilots and three cabin crew perished.

As a direct result of Flight 592 accident, Class D classification became obsolete. Legislation was enacted to increase protection from possible inflight fire by incorporation of smoke detection and fire extinguishing systems. All existing Class D cargo compartments were required to be upgraded to Class C or Class E, in accordance with FAR 121.314. Additionally, all existing detection systems were required to meet the more stringent one minute detection requirement.

Figure 2: Fire regulatory strategy

3 Detection Challenges

FAR 25.858(a), known as the 1-minute rule, states that "the detection system must provide a visual indication to the flight crew within one minute after the start of a fire". Consequently, designing a system able to detect fire in any cargo environment is always a compromise between speed (sensitivity of the detector) and signal reliability (fidelity of detection). Today's cargo fire protection systems are based on smoke detection, by identifying the presence of smoke particles. Once the threshold level of smoke particles is exceeded, the smoke detector triggers an alarm.

Almost anything can be shipped by air: letters, packages, cars, electronics, flowers, vegetables, meat, sea food, livestock, construction equipment and even airplanes. Most of the freight is stored in special containers shaped to fit the cargo hold. Some freight is placed on pallets, and loose items may be placed in any remaining open space. Cargo smoke detection systems must answer these various types of air freight which can cause different kinds of fire. Fire can be accompanied with invisible, dark or white smoke and may be characterized by several heat levels, varying from no heat to extreme heat. This wide fire protection spectrum implies that smoke detectors must have balanced sensitivity to all types of fire.

Potential false alarm scenarios (Figures 3 and 4):

- Environnemental changes: temperature, humidity, etc.
- Water condensation, either on ground after landing in a hot and humid zone, or during flight, due to temperature gradient at the cargo compartment.
- Fog or haze near air conditioning system outlets.
- Nucleic fog (can appear in certain conditions of pressure drop inside the aircraft).
- Dust accumulated on the container, blown by the air ventilation system (dust particles in suspension).
- Detector sensors stability.

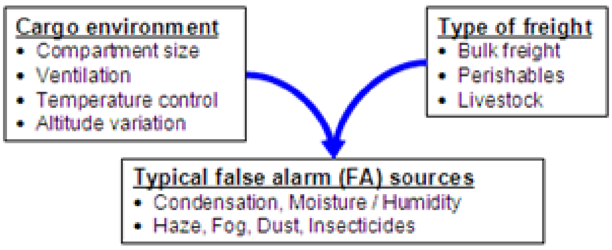

Figure 3: Typical false alarm sources

Figure 4: Fog vs. smoke environment in cargo compartments

FAA investigations demonstrate that on US registered transport aircraft (during 25 years), there was never a negligible rate of false alarms (Figure 5). A lot of efforts have been spent to reduce the false alarm rate. When the crew is unable to verify a false warning, the aircraft must land immediately.

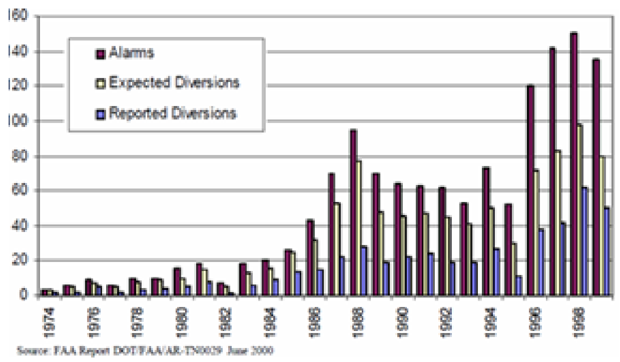

Figure 5: Diversions caused by cargo false smoke alarms

Large cargo compartments require conditioned air in order to keep freight at the desired temperature during all flight phases. High airflow dilutes smoke, making detection of low smoke levels, difficult for detectors that passively wait for smoke to reach them. Carrying vegetables or seafood in summer and in tropical areas is a real challenge, because of the high humidity levels. Smartly balancing air distribution system (if open-air smoke detectors are used), to reduce airflow intensity in the vicinity of smoke detectors, is an additional challenge.

4 Optical Smoke Detectors

There are two basic types of optical smoke detectors: open-air (free-convection) and draw-thru (duct). The free-convection type is designed for overhead mounting, for direct exposure to the ambient air. The draw-thru version is ideal for electrical bays or hidden areas, but requires a vacuum source to pull air samples to the smoke detectors. Signals from detectors are sent to the automatic fire and overheat logic and test system (AFOLTS) that provides functional tests, warning and fault indication signals to the modular avionics warning electronic assembly (MAWEA) and fire panel visual and audible indications.

Modern detectors use light-reflection to detect smoke (Figure 6). At the heart of the smoke detection, is a high-quality optical measurement chamber that screens external parasite light but optimally detects smoke particles. Photoelectric detection is sensing combustion particles entering the detector's chamber, by a 880 nm infrared light (IR) emitted from an IR light emitting diode (LED) as scattered light pulses (400 microseconds) detected by a photodiode. When smoke is present in the air entering the chamber, smoke particles scatter the IR light. The intensity of the light sensed by the light receiver is transformed into a signal sent to the fire alarm. The smoke sensing chamber is designed to exclude most ambient light influences, while permitting entry of smoke particles. The labyrinth structure eliminates water deposition or condensation, improving false alarm rejection.

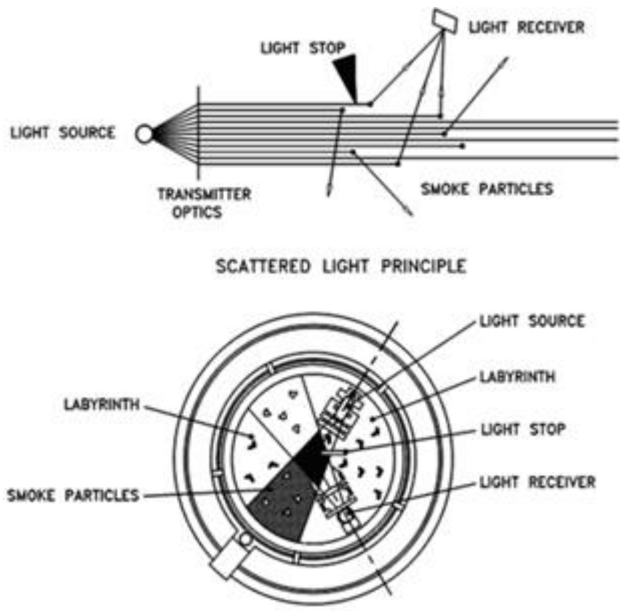

Figure 6: Photoelectric smoke detector architecture

Duct detectors, are used in air-handling systems. They are mounted directly on an air duct or nearby, with a sampling tube extending inside the duct. Air continuously flows through the detection chamber. The difference between open-air and duct detectors, is the method of getting smoke into the detection chamber. Open-air detectors rely on convection (Figure 7).

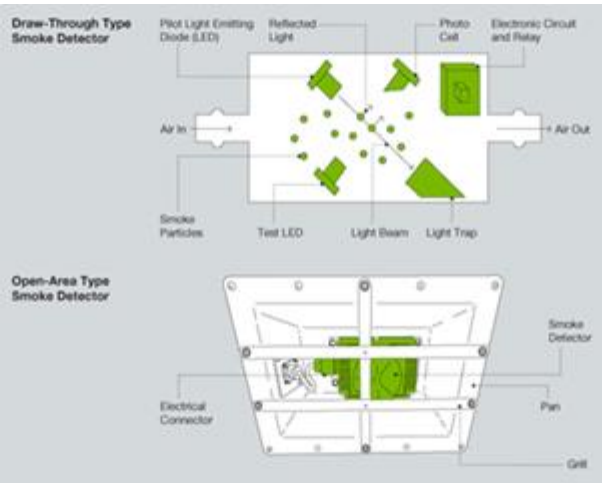

Figure 7: Draw-thru and open-air smoke detectors

The smoke detectors are microprocessor based devices, containing controlled area network (CAN) bus and discrete logic interfaces. Photoelectric detectors that share a common infrared light source, generate a signal proportional to smoke concentration. The smoke detector excludes nuisance by a particle discrimination algorithm. Smoke concentration level expressed in percent of light transmission per foot, is analyzed to determine if fire exists. The detector includes a built-in test (BIT) performed upon power application, or initiated by a push-to-test discrete input.

Multi-criteria (MCR) smoke detectors include dual optical measurement chamber, two temperature sensors, and a humidity sensor (Figures 8 and 9). The dual optical measurement chamber detector allows identification of fire type (open or smoldering) and adjusts the sensitivity accordingly.

Temperature criteria combined with optical signals, adjust detector's sensitivity to detect no smoke fire (alcohol fire). Humidity criteria prevent deceptive signals due to high humidity variation.

Figure 8: Siemens PMC11 multi-criteria (MCR) smoke detector

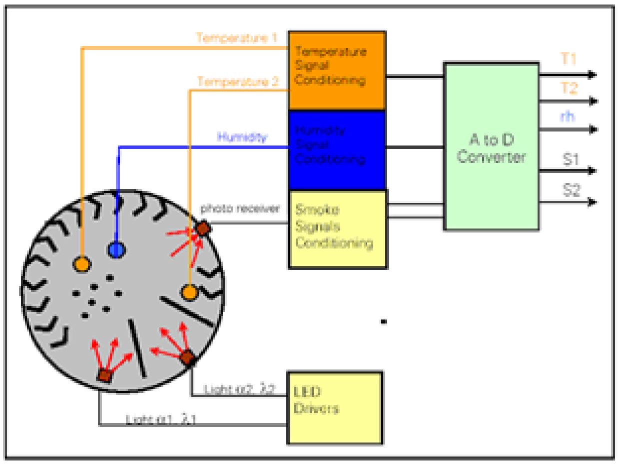

Figure 9: Multi-criteria optical measuring chamber

The performance of a smoke detector is optimized by adjusting detection logic according to environmental conditions, and smoke properties. Environmental conditions analysis allows smart detection process and thus, significant reduction of false alarms, compared to conventional detectors (Figures 10 and 11).

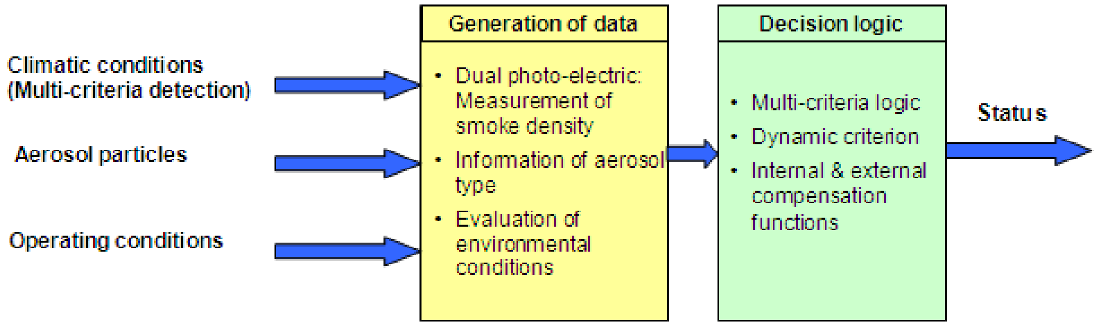

Figure 10: Multi-criteria smoke detection logic

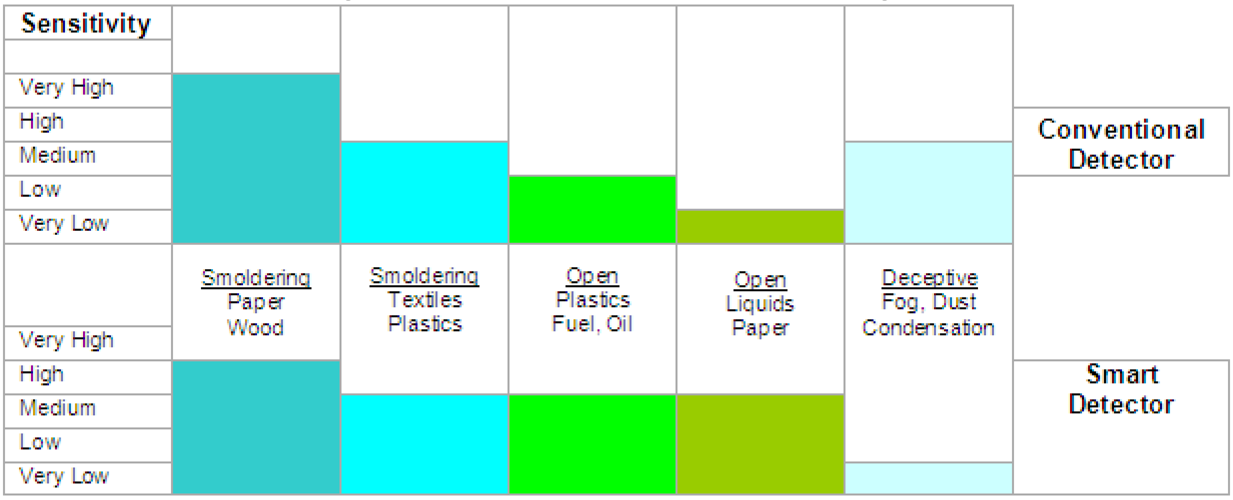

Figure 11: Multi-criteria vs. conventional smoke detector

A unique discrimination capability enables rejection of main false alarm sources, such as fog, condensation, dust and insecticides (Figures 12 and 13). The discrimination capability is based on sensitivity balancing between the different fire types and deceptive phenomena.

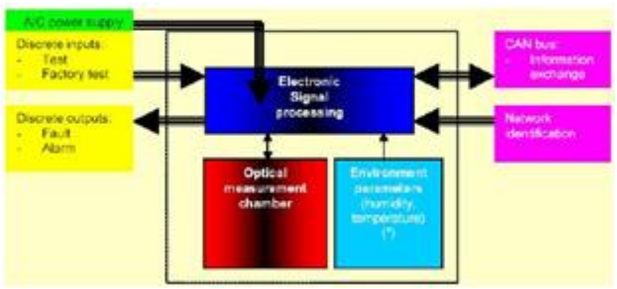

Figure 12: MCR functional block diagram

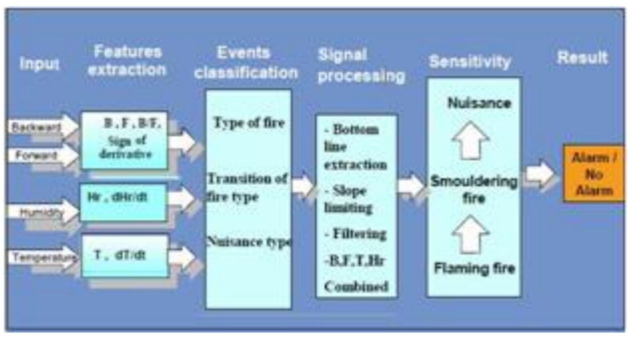

Figure 13: MCR signal processing algorithm

5 Freighter Conversions

Airfreight is an important sector of air transportation. About 10% of shipped value worldwide is transported by air. Airfreight is a vital component in the global economy. Airframe manufactures meet this need mostly with freighter versions of passenger airplanes. Additionally, there is a large number of aging airliners, 10 to 20 years old, steadily losing their market values, which are a source for conversion to freighters.

IAI's freighter conversions consist of removal of all unneeded passenger amenities and modification of the main deck to Class E cargo compartment while fwd & aft lower cargo compartments retain Class C.

Modification of air conditioning system, including change of all air distribution ducts, adding ECS to the lower cargo compartments, adding isolation valves to stop airflow in the cargo compartments in a fire situation and installation of new smoke detection systems, meeting the 1-minute detection time requirement.

6 Freighter Conversions Smoke Detection Systems

IAI Bedek Aviation Group, in collaboration with Siemens (France) Airborne Systems, developed (during the last decade) several state-of-the-art cargo smoke detection systems (SDS), for main deck and lower Class E and Class C cargo compartments.

System requirements:

- Provide a fire/smoke warning.
- Early detection, at a temperature significantly below structural integrity decrease.
- Provide functionality test procedure.
- Effectiveness through the entire operation configurations and conditions.
- No inadvertent operation.
- Comply with 25.1301 function and installation, and 25.1309 safety requirement (Table 1).

Fault Conditions	**Classification Severity**	**Requirements (per OH)**
Total loss of smoke detection in combination with a fire	Catastrophic	< 1.00 E-09
Un-indicated loss of smoke detection capability without fire	Major	< 1.00 E-05
Spurious warning of smoke in a cargo compartment	Major	< 1.00 E-05
Total loss of smoke detection in a cargo compartment zone without fire	Minor	< 1.00 E-03

Table 1: Smoke detection system functional hazard analysis (FHA)

A number of challenging goals were considered in order to ensure meeting certification requirements while having high false alarm rejection rate. The cargo smoke detection system consists of 2-LRUs (Line Replaceable Units), a cockpit control panel and smoke detectors. The entire electronics is built in the cockpit control panel. A design goal for all conversion programs was to integrate the new detection systems into aircraft systems. The smoke detection systems incorporate build-in test equipment test (BITE).

It is recognized that the probability of a fire event is less than 1.7E-07 per flight-hour. Total loss of smoke detection in combination with a fire should be less than 1.0E-09 per flight-hour. Un-indicated loss of smoke detection severity is major, therefore, smoke detection system hardware and software development assurance level (DAL) allocation meet DO-254 / ED-80 and DO-178C / ED-12C level B.

6.1 B767-200BDSF, -300BDSF Smoke Detection System

STC for B767-200BDSF was obtained in July 2004 and in December 2009 for the -300BDSF. The main cargo smoke detection system is based on draw-thru air sampling, dual loop AND logic, meeting the 1-minute rule. The 2-LRUs architecture uses duct detectors and control panel (Figures 14 and 15). The detectors sensitivity set to provide an alarm at light transmissibility of 97% (3% obscuration).

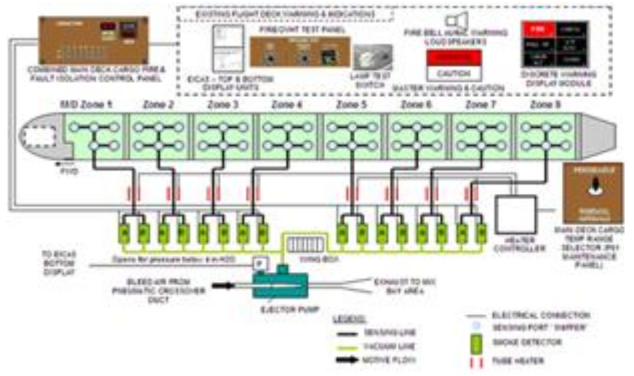

Figure 14: B767-300BDSF main smoke detection system architecture

Figure 15: Siemens CGT11 series smoke detector

The CGT11 detector, FAA Technical Standard Order (TSO) TSO-C1c approved, selected for B767-200BDSF, -300BDSF is microprocessor controlled, with false alarm rejection and optimal fire protection spectrum algorithm.

Fire is annunciated only if both loops detect smoke. If one detector is faulty, the system automatically reconfigures to a single loop mode.

Same smoke detectors are installed in the main and lower cargo for maintenance commonality. Heaters are installed on the sensing lines leading to the detectors. The heaters are regulated by a controller, activated when selecting the perishables mode (main cargo temperature maintained at 4 Celsius for perishable goods). A significant advantage of the system is low maintenance and serviceability due to the smaller number of detectors.

6.2 B747-400BDSF Cargo Smoke Detection System

STC for B747-400BDSF was obtained in May 2006 (Combi) and October 2006 (PAX). The main deck cargo compartment was classified as Class E, while the lower cargo remained as Class C (Figure 16, Table 2).

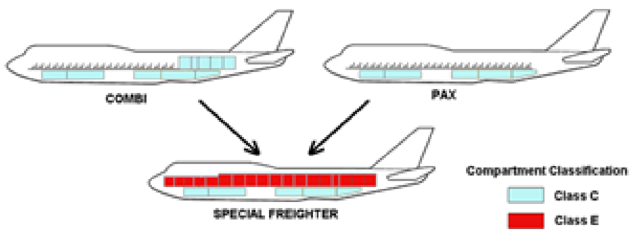

Figure 16: B747-400BDSF cargo compartment classification

	B747-400 PAX/Combi		B747-400BDSF	
	Main Deck	**Lower Holds**	**Main Deck**	**Lower Holds**
Cargo Compartment Classification	C (Combi)	C	E	C (unchanged)
Smoke Detection Time Requirement	5-minute rule	5-minute rule	1-minute rule	1-minute rule
Smoke Detection System Type	Draw-thru (Combi)	Draw-thru	Open-air	Open-air
Fire Extinguishing System	Halon concentration	Halon concentration	Depressurization	Halon concentration

Table 2: B747-400BDSF cargo fire protection system

The 2-LRUs smoke detection system consists of a controller (SDC) and Siemens PPC12 open-air detectors (Figures 17, 18 and 19).

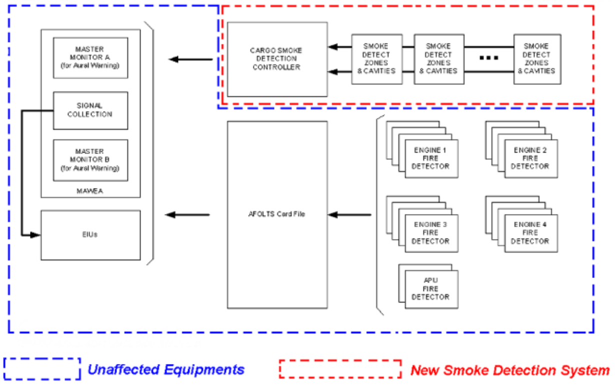

Figure 17: B747-400BDSF smoke detection system

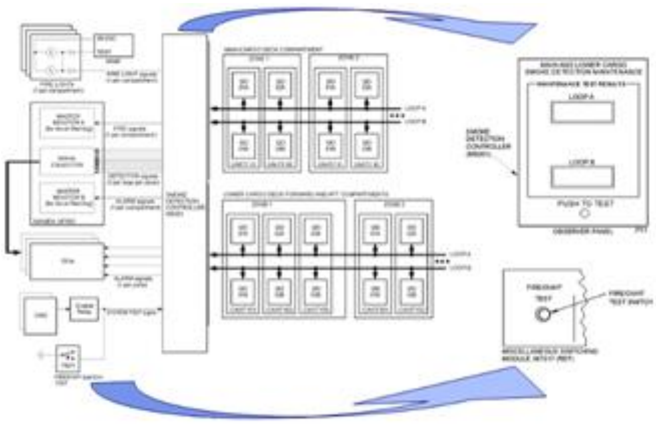

Figure 18: B747-400BDSF smoke detection

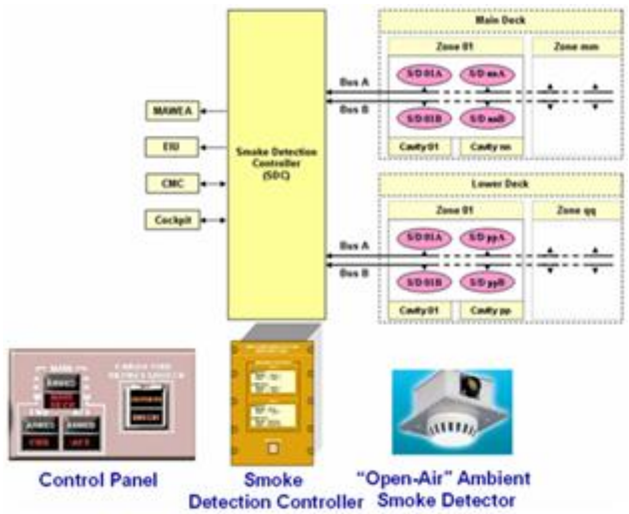

Figure 19: B747-400BDSF cargo smoke detection architecture

The SDC has two LCD screens (one per loop), that provide fault display of individual detectors. The smoke detection system includes a maintenance test mode, to identify faults of individual detectors. The smoke detection controller also functions as a maintenance panel. Maintenance test mode displays test results on the LCD screens. The maintenance test mode also identifies detectors cleaning need.

The new system uses dual loop AND logic. The system annunciates a fire only if both loops detect smoke. The system incorporates BITE capability and automatic reconfiguration to single loop if one loop fails. Table 3 presents alarm & fire compartment logic. Zone "x" represents any zone in the main cargo or lower cargo.

Zone "x"				SDS output		
Cavity "n"		Cavity "m"		FIRE Compartment (Channel A)	ALARM compartment (Channel B)	ALARM Zone "x" (reminder)
S/D An	S/D Bn	S/D Am	S/D Bm			
Nominal Mode						
Standby	Standby	Standby	Standby	OFF	OFF	OFF
Standby	Alarm	Standby	Standby	OFF	OFF	OFF
Alarm	Standby	Standby	Standby	OFF	OFF	OFF
Alarm	Alarm	Standby	Standby	ON	ON	ON
Alarm	Standby	Standby	Alarm	ON	ON	ON
Alarm	Standby	Alarm	Standby	ON	OFF	ON
Standby	Alarm	Standby	Alarm	OFF	ON	ON
Degraded Mode						
Standby	Fault	Standby	Standby	OFF	OFF	OFF
Fault	Standby	Standby	Standby	OFF	OFF	OFF
Alarm	Fault	Standby	Standby	ON	OFF	ON
Fault	Alarm	Standby	Standby	OFF	ON	ON
Standby	Fault	Alarm	Standby	OFF	OFF	OFF
Fault	Standby	Alarm	Standby	OFF	OFF	OFF

Table 3: Alarm and fire compartment logic

The smoke detectors are FAA Technical Standard Order (TSO) TSO-C1c approved, with transmissibility of 97%. The detectors are installed on dedicated pans, distributed along the main deck & lower compartments ceiling.

The smoke detection system is connected to aircraft warning devices; same as B747-400 PAX, Combi and production freighter, giving the following alert indications:

- Master warning (visual & aural)
- Fire warning indication (MAIN, FWD, AFT)
- EICAS messages (warning, status)

6.3 B737-400BDSF Smoke Detection System

STC was obtained in February 2009. The main deck was reconfigured from passenger to a Class E cargo compartment. The lower forward and aft cargo compartments were modified from Class D to Class C (Table 4).

	B737-400 PAX/Combi		B737-400BDSF	
	Main Deck	**Lower Holds**	**Main Deck**	**Lower Holds**
Compartment Classification	PAX	D	E	C (unchanged)
Smoke Detection Time Requirement	N/A	N/A	1-minute rule	1-minute rule
Smoke Detection System Type	N/A	N/A	Open-air	Open-air
Fire Extinguishing System	N/A	N/A	Depressu-rization	Halon concentration

Table 4: B737-400BDSF fire protection

The main deck smoke detection system is based on 2-LRUs architecture includes a cockpit control panel and 20 Siemens PMC11 multi-criteria open-air detectors FAA Technical Standard Order (TSO) TSO-C1d approved, using single loop logic (Figures 20 and 21).

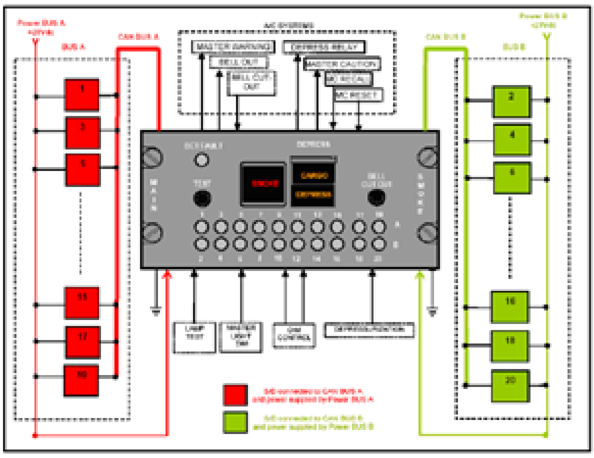

Figure 20: B737-400BDSF smoke detection

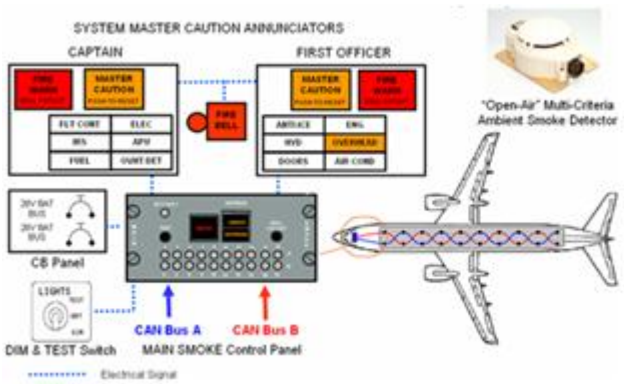

Figure 21: B737-400BDSF smoke detection displays

Any detector identifying smoke activates fire alarm (Table 5).

Smoke Detector Status (Bus A)	Smoke Detector Status (Bus B)	Smoke Status
Standby	Standby	OFF
Standby	Alarm	ON
Standby	Fault	OFF
Alarm	Standby	ON
Alarm	Alarm	ON
Alarm	Fault	ON
Fault	Standby	OFF
Fault	Alarm	ON
Fault	Fault	OFF

Table 5: B737-400BDSF smoke detection logic

Communication between the control panel and the detectors is based on a double segregated CAN bus technology, simplifying wiring and allowing digital data processing. The system detects smoke within one minute in its regular configuration. Minimum equipment list (MEL) certification was obtained for a single bus failure dispatch.

7 Qualification & Certification

IAI freighter conversions demonstrated cargo fire protection performance, reliability and compliance with safety requirements. The smoke detection systems were developed following the guidelines of aviation industry standards, including AC 25.1309-1A/AMC 25.1309, RTCA DO-160 (ED-14), DO-178B, DO-254, SAE ARP 4754 (ED-79) and SAE ARP 4761 to demonstrate compliance with FAA FAR/EASA CS 25.1309 requirements.

Flight tests showed that smoke is detected after 30 to 35 seconds. When fire occurs in the main cargo, the flight crew starts fire emergency procedures for aircraft depressurization and oxygen deprivation:

- Ventilation deactivation
- Descent (or climb) to 25,000 feet

Halon is discharged to extinguish fire in the lower compartments, while maintaining cruise altitude.

Smoke penetration tests were performed to show compliance with 25.857 by filling the main deck with smoke per FAA AC 25-9A guidelines.

No smoke penetrations to the occupied areas; flight deck and supernumerary area were observed. Tests were repeated for the lower compartments. No inadvertent smoke warning was observed, in compliance with 25.855(i).

The developed systems meet smoke detection system installation and functionality aspects in compliance with 25.1301. The development process included compliance with electro-magnetic interference (EMI) requirements of integrated cockpit control panel which includes all control hardware.

Smoke detection tests were conducted according to the guidelines of FAA AC 25-9A, to demonstrate detection time anywhere within the cargo areas and through the entire aircraft flight envelope. Each test was conducted by generating a small amount of smoke at numerous locations within the cargo compartments. Figure 22 shows a Kidde Aerospace smoke generator producing smoke according to AC 25-9A.

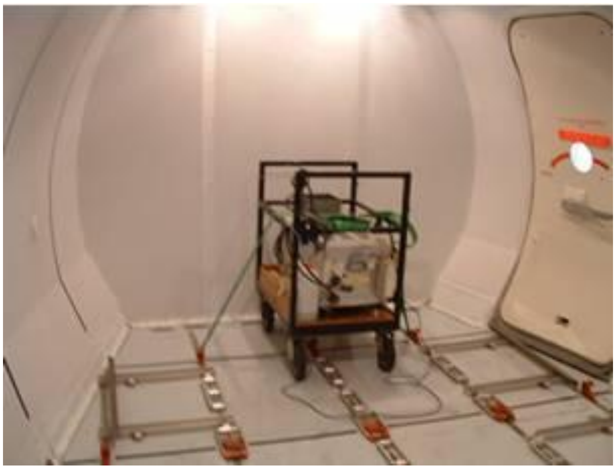

Figure 22: Smoldering smoke generator

Following the smoke detection tests, a smoke penetration test is conducted, to demonstrate sealing-proofing of occupied areas. A Rosco 1500 type smoke generator was used to reach a full-of-smoke compartment, according to AC 25-9A. The test also supports demonstration of no inadvertent operation of smoke detection for adjacent compartments; smoke is detected only in the compartment where it originates.

As a result of meeting smoke detection functional hazard analysis requirements, flight continuation to target in the event in-flight system fault was approved. Master Minimum Equipment Lists (MMELs) were certified to operate even in faulty conditions and to dispatch in case of smoke detector(s) or power failures.

8 Summary & Conclusions

Smoke detection systems are defined by the type, the area and the required level of protection. The characteristics of various aircraft environments and various smoke detection systems were examined. Incremental improvements introduced over the years, enhanced smoke detectors performance. Detectors sensitivity as a function of time and temperature became much less sensitive to threshold drift, and thus, less prone to false alarming. However, designing a cargo smoke detection system is still quite difficult, especially when conditions cannot be quantified. The key reason is inconsistent environment, which varies greatly; air can be quite hot and humid and then at altitude, temperature drops below dew point, causing condensation.

References

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