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Avionics Compartment Fire Extinguishing on the Commercial Airplanes

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Abstract

In all commercial and non-commercial airplanes, there is no fire detection or fire extinguishing system in the avionics bay. Racks, are cooled by ambient or conditioned air. Each rack will include several circuit boards, which in case of overheat, can burn with the risk of igniting the surrounding components and structures, thus jeopardizing flight safety. It becomes therefore important to provide fire detection and fire extinguishing capabilities in the aircraft avionics compartment. The approach proposed in this paper, extracts nitrogen from ambient air by mean of the Air Separator Module, then nitrogen is routed to the avionics compartment racks, and enters inside the component and extinguishes the fire. The temperature of the nitrogen is adjusted to be around 25°C to prevent thermal shock effects on the circuit boards before being injected in the avionics compartment. A series of experiments conducted, aimed at gathering information by using dry nitrogen under different pressure values to extinguish different size of fire. The analysis of the experiment research showed that increasing nitrogen pressure, resulted in quicker extinguishing time. This is because nitrogen under higher pressure, quickly decrease the oxygen concentration in the air for the fire already in the process of combustion. Nitrogen does not conduct electricity thus cause no short circuits during and after the extinguishing process, therefore, they are ideal for use in the electronic systems.

Keywords: Airplanes; Avionics

Nomenclature: ASM: Air Separator Module; AVEC: Avionics Equipment Computer; EFIS: Electronic Flight Instrument system; ECAM: Electronic Centralized aircraft Monitor; ECS: Environmental Control System; FCV: Flow Control Valve; FWD: Forward; GRU: Ground Refrigeration Unit; LVDT: Linear Variable Differential Transformer; OBIGGS: Onboard Inert Gas Generating System; MCDU: Multifunction Control Display Unit; Press: Pressure; STBY: Standby; SDCU: Smoke Detector Control Unit; SOV: Shut-off Valve; SNR: Sensor; TM: Torque Motor; T: Temperature; VLV: Valve; WXR: Weather Radar; XCVR: Receiver

Introduction

Electronic equipment in modern airplanes, is increasing and as the electronic equipment operate, heat is generated. The heat can destroy the device, unless the heat build-up at and around the component is removed or transferred away from it. The failure rate of electronic equipment increases exponentially with temperature. The ideal operating temperature for bipolar digital devices is between 22°C to 37°C. High operating temperatures in electronic equipment will jeopardize its safety and reliability. The cooler, the electronic device operates, the more reliable it is. As a rule of thumb, the failure rate of electronic components is halved for each 10°C reduction in the operating temperature. Moisture is undesirable since it causes corrosion on the wiring. Most electronic equipment is designed in a way to dissipate heat efficiently [1]. Each computer contain several circuit boards, and in case of overheat, it can burn out and result into fire. For illustration, transient suppression devices are designed to react suddenly and momentary to an overvoltage conditions such as voltage spikes to protect the electronics devices. Examples of transient suppression devices are Zener diodes, Metal Oxide Varistor (MOV), and they have a life time [2]. A varistor is an electronic component that is widely used in electronics; its electrical resistance varies with the applied voltage. If a varistor (MOV) exposed to increased voltage for a longer duration than microseconds, its temperature increases rapidly and exceed its ability to dissipate the heat thus resulting in a thermal runaway condition and fire. For illustration, metal oxide varistors if subjected to energy surge beyond its peak rated current, it can result in degradation and catastrophic failures. Tests were conducted to induce thermal runaway to 40 mm MOV with 130 Volts AC, during the test 240Volts AC were applied at 15 amps and the MOV ignited, as shown in Figure 1 [3]. Zener diodes are used as overvoltage protection; it does not provide fool proof protection because if the surge voltage is about twice the diode operating peak voltage then the surge voltage will be let through [4]. Therefore, it is essential to extinguish any fire in the electronic equipment before it spread out, and result in a catastrophe.

There are mainly two types of aircraft avionics bay cooing system. Air-

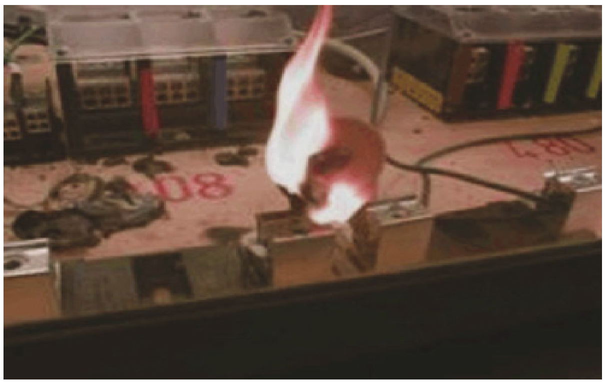

Figure 1: Showing catastrophic failure of Metal Oxide Varistor during tests, Source: Brown, 2013.

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cooling is the most common technique used in large transport, aircraft avionics compartment. The first type is an unconditioned bay where the internal environment (pressure, temperature, and humidity) is not controlled, and environmental control system (ECS) cooling air is not supplied to any of the equipment. The second type is an air-conditioned avionics bay where ECS supply the cooling air to the equipment, known as forced air cooling, where heat is transferred to cold air supplied by the aircraft ECS. This cooling approach is used in all commercial large transport airplanes. The cooling airflow passes through a heat exchanger installed on the aircraft skin (to cool the airflow further) then supplied to the equipment on the rack. The equipment on its base has ventilation ports for cooling air to enter. The cooled air enters the box at a temperature and exists at a higher temperature after absorbing the heat dissipated within the boxes. The cooling air, is discharged either overboard (if aircraft is on ground), or discharged to the forward cargo compartment, to heat up the compartment during flight, such avionics cooling system installed on Airbus A330/340 series. In this paper, only forced air-cooling of conditioned avionics compartment is discussed.

At present, flight crew is unable to assure a safe return to ground in the event of an avionics compartment fire. Pilot concerns, has not being taken into consideration by the aircraft designers and the airline [5].

Aircraft Type	Registration	Date	Flight Number	Departure From	Arrival To
Airbus A320	G-GATK	21 July 2016	BA-2552	London Gatwick	Heraklion Greece
Airbus A320	G-EUUH	21 April 2016	BA-793	Gothenburg Sweden	London Heathrow
Boeing B777	G-VIIU	17 March 2016	BA-2153	London Gatwick	Bridgeton Barbados
Airbus A321	G-EUXC	14 Sept. 2015	BA-432	London Heathrow	Amsterdam Holland
Boeing B777	G-VIIY	12 July 2015	BA-2158	Saint Lucia	London Heathrow
Boeing B777	G-VIIA	4 Sept. 2015	BA-143	London Heathrow	Delhi India
Airbus A319	G-EUPJ	24 July 2015	BA-718	London Heathrow	Zurich Switzerland

Table 1: British airways fume in cockpit incidents [12].

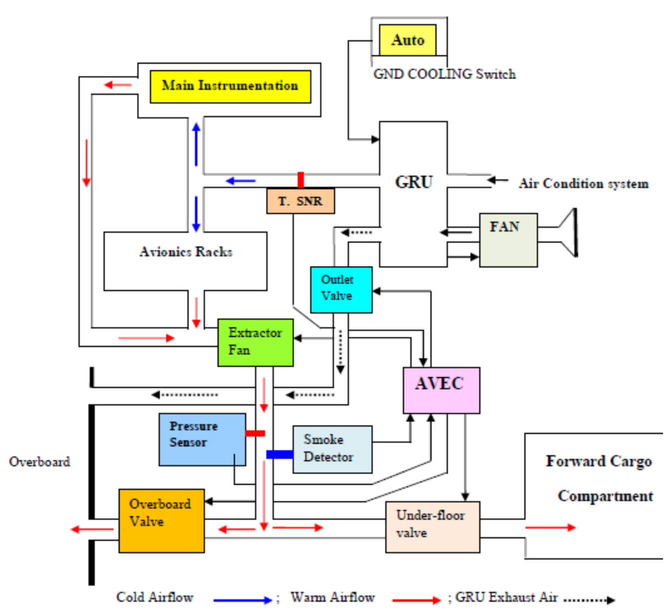

Figure 2: A simplified aircraft avionics equipment cooling system on Airbus A340.

“Occurrence of smoke or fire on board of commercial airplanes during flight is a dangerous situation. If not dealt with effectively by the crew, it can result in disaster” [6].

During a 38-month study from January 2002 to December 2004, the International Air Transport Association (IATA) found 2,596 reports related to fire/smoke/fume/spark occurrence, and 525 (205) were false warnings resulting in 11% of in-flight diversions due to false warning [6]. Sometimes, the fume/smoke in the cockpit, can be due to avionics compartment smoke or fire.

In all modern airplanes, there are several smoke detectors installed in line with the avionics cooling system, which sense any smoke vapor thus generate warnings in the cockpit. Current avionics smoke procedure on large transport airplanes, states that pilot has to make certain selection, which allows air from the air condition system to be routed to the avionics compartment cooling system and to blow out the smoke overboard. If the avionics smoke warning does not disappear in five minutes, then pilot must land as soon as possible to a nearest airport and declare an emergency. The main risk is that the nearest airport to land could be very far away and, especially if aircraft is flying over water, then fire could spread out and result into catastrophe. Three elements a fire needs to ignite: heat, fuel, and oxygen. To prevent a fire, one of the elements needs to be eliminated or reduced beyond certain limit. The main risk with current procedure is that air rich in oxygen is supplied to the avionics bay to blow out the smoke overboard; however, it feeds the fire with fresh oxygen and it can spread further.

In the proposed design, nitrogen is extracted from ambient air by using Air Separator Module (ASM), then it is routed to the avionics equipment cooling system (where all computers cooled in their racks), nitrogen enters the computer through the ventilation holes on the base. Nitrogen is first cooled by passing through a heat exchanger, then its pressure increased by the pump in order to extinguish the fire more effectively, then routed to the avionics equipment compartment. At the same time, the cooling air supply to the avionics compartment is stopped, in order to prevent oxygen to feed the fire in the compartment, therefore only nitrogen is used to extinguish the fire. In the proposed technique, the avionics fire extinguishing system can operate in manual or automatic mode. If auto-mode is selected then when there is an avionics compartment smoke warning is generated, the system isolate the avionics compartment from oxygen (cooling air supply), and supply nitrogen to the compartment to extinguish fire. When fire or smoke warning is no longer detected, the system returns to normal operation. Fire requires three elements: oxygen, fuel and ignition source. In the proposed system, the supply of fresh air containing (oxygen) to the avionics compartment is isolated [7-10].

The sources of fumes in the cockpit and or cabin can be due to many factors [11]. One of the other sources of smoke in the cockpit, it can be from fire or smoke in avionics compartment, which is usually located below the flight deck. There have been number of cockpit smoke condition incidents, Table 1 shows British Airways flights which experience cockpit smoke incidents. In all the British Airways cockpit fume incidents, flight crew donned their oxygen masks and declared an emergency [12].

Current Avionics Equipment Cooling System

In Airbus fleet, with reference to Figure 2, the avionics equipment is cooled by air supply from air condition system. When the cooling air

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cools the equipment then it is routed to either to forward cargo through the underfloor extract valve during flight mode or dumped overboard if aircraft is on ground through the overboard extract valve. When there is an avionics smoke warning as detected by the smoke detectors in the avionics bay, it generate a warning signal. The fault light on extract pushbutton illuminate and pilot must select it to override which causes the overboard extract valve to partially open. This allows the extract fan to extract air through avionics bay racks where computers are installed and to be routed overboard, in order to get rid of smoke. However if smoke warning do not disappear within 5 minutes then pilot must make an emergency landing as soon as possible hence message LAND ASAP appears on ECAM. Pilot has to use oxygen mask and switch off all the electrical loads on galleys by pressing commercial switch.

When aircraft is operating in hot climates, an optional ground cooling system can be used in avionics cooling system, as installed in Airbus fleet, shown in Figure 2, to provide additional cooling of the avionics equipment. The airflow to the avionics equipment bay is cooled by a refrigerant fluid cycle system called the Ground Refrigeration Unit (GRU). It consists of a Freon gas close cycle refrigeration system, which operates on the conventional compression/expansion principle. In GRU, the refrigerant fluid passes to the evaporator where it absorb the heat and transform into a gaseous state by cooling the air blown to the avionics. GRU operates under certain conditions, if aircraft is on ground, with engine off and pack off, and the ambient temperature exceeds 27.5°C. The GRU automatic shutdown occurs when the temperature drops below 23°C.

Operation of Proposed Avionics Smoke Extinguishing System

In the proposed design, OBIGGS is used to extract nitrogen from air. Nitrogen is supplied to the avionics bay instead of bleed cooling air. Before applying nitrogen to the equipment cooling, the avionics cooling

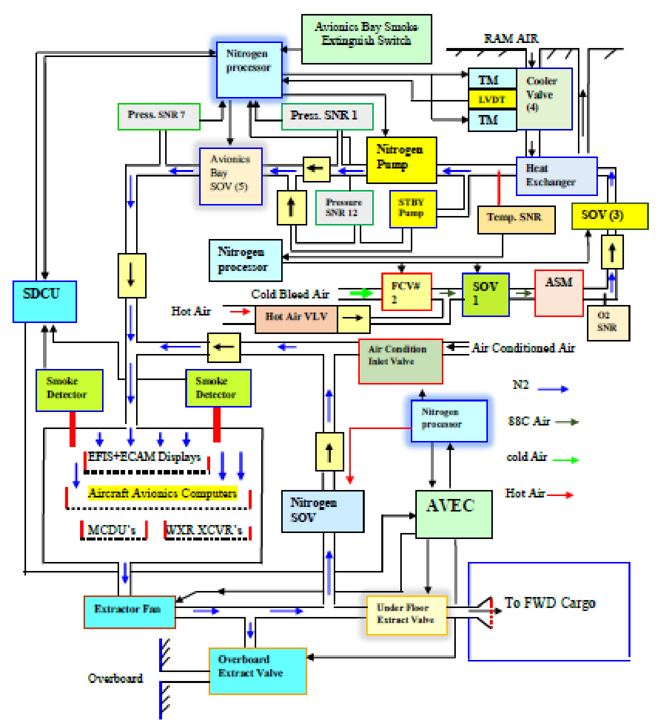

Figure 3: Proposed design of avionics compartment fire extinguishing system.

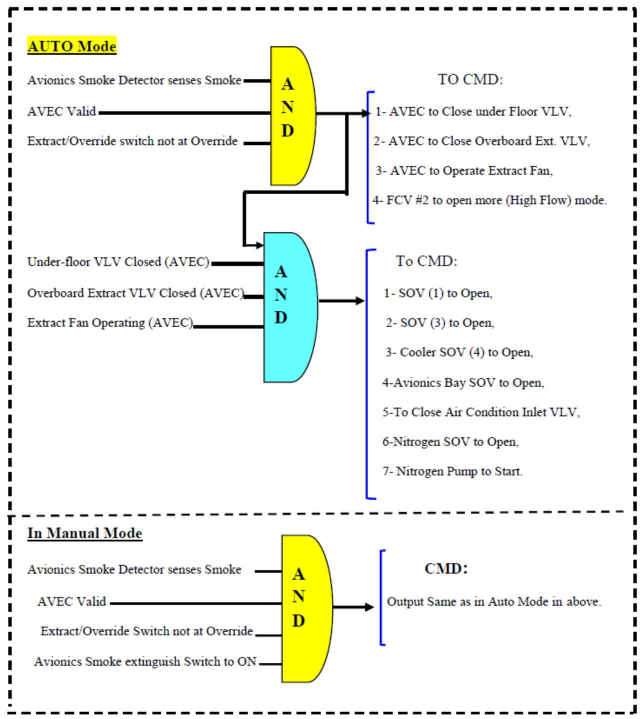

Figure 4: The logic requirements in the nitrogen processor for the proposed design of avionics smoke extinguishing system.

air supply to the avionics bay isolated, in order to prevent oxygen to reach the smoke /fire in the avionics bay. Nitrogen temperature is controlled to be between 20°C to 25°C, because the ideal temperature for bipolar digital devices is between 22°C to 37°C.

In OBIGG, the bleed air supply to ASM's is heated to reach optimum temperature of 180 F -/+ 10F, in order to increase the efficiency of air separator modules [7]. Therefore, the nitrogen generated from ASM is in region of 88C. The reliability of the electronic components decreases with increasing temperature. Hence, the nitrogen temperature is monitored continuously and reduced to be between 20°C to 25°C. The nitrogen temperature should not be too cold to cause a thermal shock to electronic devices, neither too hot, to result in overheating and or destruction of the sensitive devices. Failure rate of avionics component is typically assumed to increase exponentially with temperature [8].

In the proposed design of avionics equipment fire extinguishing system, it operates in two modes of operations, the auto and manual modes. In Auto-mode, with reference to Figures 3 and 4, in case of avionics smoke detection, nitrogen is applied automatically to the avionics equipment cooling system, and ECS cooling air supply to the bay stopped (to prevent oxygen to reach smoke/fire). In auto mode, the followings events will occur: the shut-off valve SOV (1) opens to allow hot bleed air supply to feed ASM. SOV (3) opens to let nitrogen flow through the heat exchanger in order to reduce temperature of nitrogen. Ram air through the heat exchanger is used to cool the nitrogen. Cooler SOV (4) opens to let ram air through the heat exchanger, and is controlled by two torque motors. Cooler SOV (4) modulates the opening port of the valve, in order to control the nitrogen temperature to the required temperature value of 20° to 25°C. Usually one torque motor is active and in case of failure, the second torque motor takes over. Two LVDTs, one for each torque motor, sense the position of the valve and supply position feedback to the controller. Nitrogen Pump used to pressurizes nitrogen in order to increase the nitrogen extinguishing ability, so that fire is extinguished quickly. If nitrogen pump fails, the pressure sensor 1 senses low pressure, and the processor will command the standby pump to run so that the standby pump is used only in emergency case when the main nitrogen pump fails. FTPC generates failure message about the nitrogen pump failure so that corrective maintenance action will be taken. Flow Control Valve (FCV #2) commanded by nitrogen processor to open more, to increase the airflow to (ASM's) in order to increase nitrogen output from ASMs. In addition, the processor commands the air compressor to operate, in order to pressurize the supply air inlet to ASMs to 65 psi. This will increase ASMs nitrogen flow rate.

In Airbus fleet, the avionics equipment cooling is controlled by AVEC, so in proposed design; nitrogen processor sends a signal to AVEC in order to close the under floor extract valve, and overboard valve plus to operate extract fan. The micro switches detect the positions of the valve, therefore, when AVEC confirms that the closure of under floor valve, overboard valve and operation of extract then nitrogen processor command to close Air Condition Inlet valve, in order to prevent fresh oxygen supply to avionics equipment, which it is coming from the aircraft air conditioning system. When, the air condition inlet valve is closed, and then avionics bay SOV (5) and Nitrogen SOV opens. Underfloor valve closes, to stop nitrogen to flow to forward cargo. Overboard valve closes to stop nitrogen to be dumped overboard. Extract fan operate to draw the nitrogen and recirculate it around the avionics equipment. Air condition inlet valve closes to stop oxygen flow to the avionics equipment system, to ensure fire does not spread. Nitrogen SOV open to allow nitrogen only to recirculate around the avionics equipment. Nitrogen is not toxic and crew can use oxygen mask if necessary in case of smoke entering cockpit. When fire/smoke is extinguished, the avionics equipment smoke detectors sense no smoke, the nitrogen processor stop the nitrogen flow to avionics compartment after a time delay of 3 to 5 minutes, in order to ensure that fire do not reoccur again. After the time delay, when fire is extinguished and the smoke detectors no longer sense smoke, the nitrogen processor command the followings: the nitrogen pump stops, avionics bay SOV (5) and cooler SOV (4), Nitrogen SOV, SOV (3) and SOV (1) will close in order to stop nitrogen flow to avionics equipment. Air condition inlet valve opens to let air supply from aircraft bleed system to cool equipment in avionics bay.

In Manual Mode; when pilot receives an avionics smoke warning in the cockpit then pilot must select the avionics smoke switch to ON and provided pilot has not selected extract pushbutton to override, the following actions will occur: nitrogen processor command AVEC to close under floor valve, overboard extract valve and extract fan to operate. Then it command to open, SOV (1), SOV (3) opens, Cooler SOV (4) open, Nitrogen Pump to operate and Flow control valve (FCV # 2) to open more to increases the airflow to air separator modules to keep up with the increased demand. Air Condition Inlet Valve closes to isolate avionics equipment from aircraft bleed system, and Nitrogen SOV opens. As soon as avionics smoke warning disappears, pilot has to select avionics smoke extinguishing switch to OFF. Currently on Airbus fleet, when there is avionics smoke warning in the cockpit, pilot must select extract pushbutton to override. This action causes AVEC to open overboard extract valve, and close under floor valve and ensure extract fan operating. If pilot select Extract pushbutton to override, it will inhibit the automatic and manual avionics bay extinguishing system because pilot may want to get rid of the dense toxic fume or smoke in the cockpit although the pilot can use oxygen mask. However, to increase flight safety, in proposed design, it allows pilot to select the Extract pushbutton to override, in order to get rid of smoke in cockpit and in avionics bay. When override is selected, the proposed designs of avionics smoke extinguish system will be inhibited. When the smoke is cleared from cockpit, then pilot have to de-select the override mode on the Extract pushbutton and select avionics smoke-extinguishing switch.

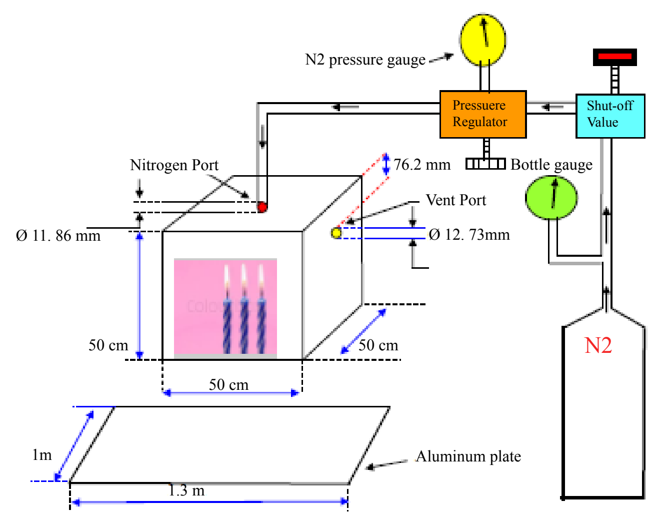

Figure 5: Experimental setup.

For the safety reason, in order to avoid any health-related issues, during nitrogen operation, the flight crews have to use their oxygen masks, because nitrogen displaces the air (which contains oxygen) in a the given space. Although, in the proposed design, nitrogen does not enter the cockpit space, however as a safety measure crew have to use their oxygen masks. The Occupational Safety and Health Administration requires that no one to enter a space with less than 19.5% oxygen without a self-breathing apparatus [9]. However, nitrogen is non-toxic, suitable for occupied spaces and, is being listed and approved by the environmental Protection Agency and International Organization for Standardization [10].

Advantages

The advantages of using nitrogen as follows: It minimizes smoke from the avionics compartment to enter the cockpit and impair the pilot judgment and or vision. Nitrogen is very suitable to extinguish fires involves energized electrical equipment [6]. The extinguishing agent is non-corrosive, and does not require a clean-up unlike most extinguishers. There are no degradation byproducts resulting from manufacturing or use of nitrogen gas. Nitrogen gas is not a global warming gas, and it does not result in ozone depletion as compared to Halon. Nitrogen is one of effective and natural extinguishing gases, and readily available in atmosphere. It does not conduct electricity thus cause no short circuits during and after the extinguishing process. Therefore, they are ideal for use in electrical and electronic systems.

Nitrogen Experiments

Experiments were performed to evaluate the effectiveness of nitrogen in extinguishing fire in a compartment determine if the size of fire affects the nitrogen fire extinguishing ability, determine the time it takes for the fire to be extinguished and determine the minimum pressure for nitrogen to be effective in extinguishing the fire. The first experiment was performed using a transparent, 50 cm, cubic box. The top side of the box his equipped with a port for the nitrogen input connection, as shown in Figure 5. The experiment is at first performed with only one candle and carried out using one lit candle, and then

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the number of candles was increased. Experiment conducted initially with the test box having no ventilation. The nitrogen shut-off valve was opened manually, in order to allow nitrogen stored in the bottle to flow to the nitrogen pressure regulator, and then the pressure regulator was manually adjusted in order to control the nitrogen pressure. Experiment was first conducted with the test box having no ventilation to atmosphere, in order to analysis the effectiveness of nitrogen. Then the same experiments conducted with the test box having a ventilation port of 12.73 mm, this is done in order to establish if nitrogen can effectively extinguish fire in ventilated container (test box).

Analysis of the Experiments

A series of experiments conducted, aimed at gathering information by using dry nitrogen under different pressure values to extinguish different size of fire. Table 2, shows the nitrogen pressure and time taken to extinguish different sizes of fire inside the test box during the experiments. The analysis of the experiment research showed that increasing nitrogen pressure, resulted in quicker extinguishing time. Figure 6, shows increasing nitrogen pressure, results in extinguishing the fire of the same intensity quicker. This is because nitrogen under higher pressure, quickly decrease the oxygen concentration in the air for the fire already in the process of combustion. In principle, there are two approaches to fire suppression: either decreasing the

Number of Lit Candles	Nitrogen Pressure (psi)	Extinguishing Time (sec)
1 to 5	5	1.16
5	2	3.73
5	4	3.20
5	5	2.70
5	6	2.60
5	8	1.80
5	10	0.51
10	2	4.22
10	5	1.32
10	10	1.28
20	2	4.32
20	5	2.30
20	10	2.22
30	2	4.50
30	5	3.35
30	10	2.54
50	5	3.45
57	10	3.48

Table 2: The nitrogen pressure and time taken to extinguish different fire intensity inside the test box.

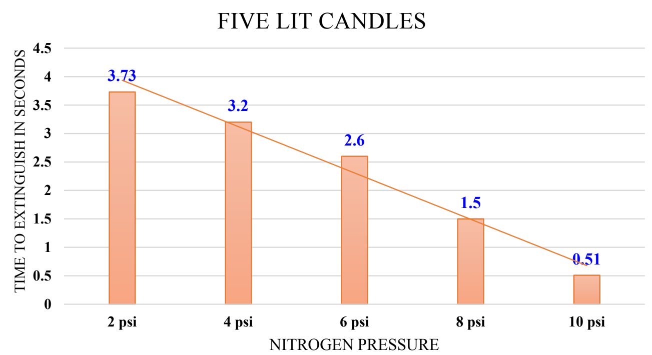

Figure 6: The chart for using different nitrogen pressures to extinguish five lit candles.

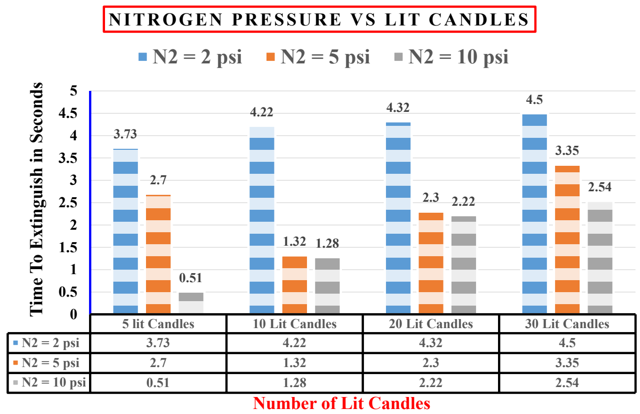

Figure 7: Nitrogen experiments chart shows that using nitrogen at higher pressures, it extinguish fire quicker.

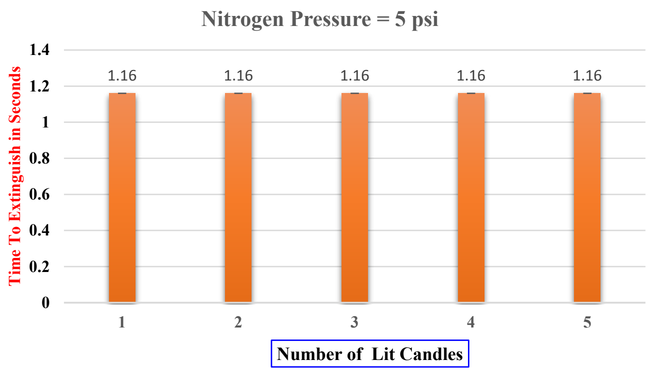

Figure 8: Nitrogen pressure of (5 psi) to extinguish candles from one to five lit candles.

oxygen concentration or inerting the combustible environment. For fire to occur, it requires oxygen, and by supplying nitrogen at higher pressure, nitrogen pushed away the oxygen from fire at faster rate, hence inhibited combustion process sooner. However, increasing the fire size, it took slightly few seconds longer time. For illustration, five lit candles were extinguished in 0.51 seconds by using nitrogen at 10 psi, however, increasing fire size to 30-lit candles took 2.54 seconds to extinguish when nitrogen supplied at 10 psi, as shown in Figure 7. The experimental study of this research shows that nitrogen did not require a cleanup after the fire event experiment, as the result of gas release. Nitrogen discharge did not create a fogging effect hence vision wasn't compromised or obscured, unlike most fire-extinguishing agents. Nitrogen did not damage protected sensitive equipment. It can be concluded that dry nitrogen is non-conductive and can be used in environments where sensitive electronic devices are present.

Combustion cannot occur when the oxygen concentration of air at normal pressure reduces to approximately below 13%. Nitrogen extinguishes the fire by displacing the oxygen from fire and starving the fire from oxygen [10].

Figure 8 shows one to five lit candles were extinguished in the same time when supplied with same nitrogen pressure (5 psi). Figures 7 shows dry nitrogen was used at different pressure to extinguish different size of fire, and time to extinguish fire was recorded. Based upon the experimental research, the analysis showed that minimum of 2 psi was sufficient to extinguish fire effectively. In addition, fire intensity size, did not have effect on nitrogen ability to extinguish the fire.

Future Work: Although, FAA have conducted extensive ground and flight tests on using nitrogen from ASM to inert center fuel tank compartment on Airbus A320, as published in FAA document: DOT/FAA/AR-03/58, which states that the results of the tests indicated the concept of the using nitrogen from ASM found effective. However, it would be advantageous, to perform an experimental study using dry nitrogen from ASM to extinguish fire in a typical avionics compartment, which is beyond the scope of this dissertation. The actual aircraft cargo compartment can vary from one aircraft type to another. The experiment had limitation due to difficulties in building a typical aircraft avionics compartment bay with racks and computers. The theoretical and practical achievement of this research can certainly be considered as an important milestone in the road-map to perform more research in future [13].

Discussion and Challenges

In the proposed approach, different methodologies can be used to increase the flow rate from the ASM and hence overcome the current OBIGGS flow rate limitation. Experiments have been conducted, result showed that nitrogen flow of ASM approximately doubled for the two-membrane configurations [9]. For ASM efficiency, the inlet air pressure has to be high (typically 40 psi or more). It is possible to operate at lower pressures but more ASMs are required and this increases weight with each ASM weighting approximately 27kg. For illustration, if the air-supply inlet pressure to ASM is at 15psi, then ten ASMs are required, but if the inlet air pressure is at 56psi, then only two ASMs required to provide the required NEA capacity [14]. A single ASM at altitude of 32,000 feet, if the ASM inlet pressure is 32 psi, then ASM nitrogen flow rate will be equal to 8 cubic feet per minute (SCFM). At 40,000 feet, if ASM inlet pressure is 40 psi, then ASM nitrogen flow rate will increase to 10 cubic feet per minute [15]. In proposed design, air compressor used to increase the pressure of air supply inlet to 65 psi to ASMs.

ASM performance can be increased if the ASM fibers are made from nanoparticles materials. Several experiment tests conducted involving membranes based gas separation, involving the hollow-fiber membranes made from three different types of fibers, such as pure polycarbonate, polypropylene, and polycarbonate added with silica nanoparticles. Gas permeabilities of O_2, N_2 and CO_2 were measured to determine the gas separation properties of obtained hollow fibers, and the test results showed that nanoparticles increased the absorption of gas separation, and improved selectivity [16].

Conclusion

In all commercial and non-commercial airplanes, there is no fire extinguishing system for avionics bay smoke or fire, and pilot has to declare an emergency and land to nearest airport. Electronic equipment in modern airplanes is increasing and heat (fire) can destroy the sensitive electronic devices which are vital for safety, unless the heat build-up at and around the component is removed or transferred away from it. The failure rate of electronic equipment increases exponentially with temperature. The proposed approach uses nitrogen from ASM to extinguish fire/smoke in the avionics compartment. Nitrogen temperature from ASM adjusted to 25°C, then routed to the avionics equipment devices. Analysis of the nitrogen experiments show that nitrogen did not require a cleanup after the discharge, nonconductive, noncorrosive and suitable to extinguish fire in sensitive devices. In addition, the experiment result showed that increasing the nitrogen pressure, it resulted in extinguishing the fire quicker. Nitrogen is in fact suitable to suppress class A - petroleum products, cellulosic materials, and polymers – class B – flammable or combustible liquids – and class C - energized electrical equipment – fires [9].

After the TWA Flight 800 crashes over the Atlantic Ocean in July 17, 1996, killing all 230 people, was essentially caused by the explosion of the flammable fuel vapors in the center fuel tank explosion. Since then, FAA with assistance of several aviation companies developed an Onboard Inert Gas Generation System (OBIGGS), which ASM to extract nitrogen from the supplied air. In the proposed system design, nitrogen from ASM can be used to the avionics compartment to extinguish smoke and or fire. Most modern airplanes such as Boeing 777, Airbus 320/330/ 340 series have center fuel tank inert system, which uses ASM to generate nitrogen and to inert the center fuel tank, in order to minimize fuel tank explosion. Therefore, using the proposed design approach would not be costly.

The proposed design of using nitrogen generated from OBIGGS is the best option, because dry nitrogen can flow to all electronic devices in equipment, through the ventilation ports of the device, enter inside the component, and extinguish the fire. In addition, OBIGGS in installed in all new Airbus and Boeing aircraft, and nitrogen can be used to extinguish fire in avionics bay. In order to increase the flow rate of OBIGGS, the bleed air supply inlet to ASM have to be increased or several ASMs can be used in parallel or to use a larger ASM. This will increase the weight, however it increases the flight safety and saves the lives of passengers and the crew, by extinguishing the fire effectively, and it minimizes toxic fumes to enter the cockpit and affecting the health of pilot. Nitrogen has the ability to extinguish fires involve energized electrical equipment; therefore, it makes it ideal to use to extinguish fire/smoke in the aircraft avionics compartment.

References

1. Anonymous (2016) Cooling of electronic equipment. McGraw Hill Higher Education, USA p: 15.
2. Sivan L (1994) Microwave tube transmitters. series 9 London Chapman & Hall: 232.
3. Brown Keneh (2013), "Metal Oxide Varistor Degradation" published bu IAEI News
4. Tim W (2005) The circuit designer's companion. (2ndedn), Oxford, Elsevier p: 247.
5. Captain Adams K (1999) A new approach to cockpit and cabin fire safety. Enhancing safety in the 21th Century Airline Pilots Association, Flight Safety Foundation Conference, Brazil.
6. Royal Aeronautical Society (2013) Smoke, fire and fumes in transport aircraft. Past history, current risk and recommended mitigations (2ndedn).
7. FAA (2013) Development and testing of the FAA simplified Fuel Tank Inerting System. FAA Fire Safety Branch, USA p: 1-6.
8. Allan KD, Avram BC (1983) Thermal analysis and control of electronic equipment. McGraw-Hill, New York.
9. FAA (2012) Options to the use of halons for aircraft fire suppression systems-2012 Update Document No: DOT/FAA/AR-11/31, U.S Department of Transportation, USA.
10. Ted MA, Yamada N (1998) Nitrogen gas as a halon replacement. Halon Options Technical Working Conference, USA p: 330-338.
11. Airbus (2013) Airbus technical magazine, "FAST # 52 A Clean APU", Airbus, France.
12. AeroInside (2016), "Airline Incidents For Airlines British Airways", online database.
13. Cai Y, Bu X, Lin G, Sun B, Zeng Y (2015) Experimental study of an aircraft fuel tank inerting system. Chinese Journal of Aeronautics 28: 394-402.
14. Massey EA, Das A, Joshi P, Mahes S (2013) On board inert gas generation system. United States Patent: US 20130341465 A1.
15. William CM, Morrison R (2016) Development and testing of the FAA simplified fuel tank inerting system. Fire Safety Branch, Federal Aviation Administration, USA.
16. Moghadassi A, Marjani A, Shirazian S, Moradi S (2011) Gas separation properties of hollow-fiber membranes of polypropylene and polycarbonate by melt-spinning method. Asian J Chemistry 23: 1922-1924.