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Nuisance Alarms in Aircraft Cargo Areas and Critical Telecommunications Systems: Proceedings of The Third NIST Fire Detector Workshop

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AIRCRAFT CARGO AREA FIRE DETECTION

Overviews of fire detection in aircraft cargo areas were presented by David Blake of the Federal Aviation Administration, John O'Sullivan of British Airways, Scott Hammann of Boeing Company, and Matt Kolleck of Booz-Allen & Hamilton. The breakout discussion sessions were headed by Thomas Cleary of NIST and David Blake of the FAA. The following sections are a synthesis of their comments.

Background

Cargo areas of commercial aircraft are categorized according to their size and accessibility as described in the *Code of Federal Regulations* (CFR).[7] Class A and B cargo areas are accessible in flight, so that a fire can be suppressed by the actions of a crew member with a hand-held extinguisher. A class C cargo area is inaccessible in flight. Remote fire detection and suppression capabilities are required for class C spaces, as well as fire resistant wall panels. If an inaccessible (in flight) cargo volume and ventilation rate are limited in magnitude (leakage rate in ft^3/hr plus volume in ft^3 is less than 2000), the space is specified as class D. In the past, class D cargo areas were exempt from requirements for automatic fire detection and suppression as long as the space was totally enclosed and the cargo liner materials met stringent fire resistance requirements. On freighters, cargo spaces specified as class E are required to be equipped with fire detectors and independent ventilation control, but not fixed fire suppression systems. The FAA recently issued a Notice of Proposed Rulemaking[8] that requires fire detectors and suppression systems for all inaccessible cargo compartments, effectively converting class D cargo areas on passenger aircraft to class C. For freighters, the option exists to convert class D spaces to either class C or class E. If adopted, the rule would affect approximately 3000 aircraft that fly in the U.S. and increase the total number of spaces monitored by fire detection systems by about a factor of three.

The detectors most commonly used in class C cargo areas sense the presence of airborne particulates and aerosols. There are three basic types: radioactive ionization, photoelectric light scattering, and photoelectric light attenuation. These are sometimes supplemented by a thermal sensor.

Several detectors can be mounted on the cargo compartment ceiling where they measure the local smoke concentration, or a dual detector can be mounted remotely with an aspirated gas sampling system used to pull material into the detectors from multiple locations. When the smoke and/or temperature exceed a threshold level, an alarm is triggered in the cockpit and the crew responds according to established procedures written in the *Aircraft Flight Manual*.[9]

Cargo compartment fire detection instruments are described in TSO C1c.[10] Smoke detectors are required to alarm when the light transmission is reduced between 4 % and 16 % over a 0.305 m (1 ft) distance. (This is a much larger obscuration level than required by UL 268[2], which states that smoke detectors must alarm between 0.5 % and 4 % for gray smoke, and between 0.5 % and 10 % for black smoke.) The detectors must sense the presence of fire in the cargo compartment within one minute of ignition, according to FAR[7] 25.858. The system is evaluated as installed in the aircraft to be certified by simulating a fire with, for example, theatrical smoke. All fire detectors must withstand environmental temperatures from -30 °C to 50 °C (-22 °F to 122 °F), absolute pressures from 18.6 kPa to 104 kPa (simulating elevations from below sea level to 12 160 m (40 000 ft)), a relative humidity between 0 and 95 %, and vibrations in excess of what would normally be expected on an airplane. Thermal detectors, if present, are set typically to alarm at 88 °C (190 °F) or less.

Class C cargo areas are inaccessible in flight, so that in the event of a detector alarm the usual crew procedure is to discharge fire suppression agent. With halon 1301, the amount needed to keep the fire under control is small (less than 5 % by volume), and the corrosivity and toxicity levels are low enough that an unneeded discharge causes little collateral damage to the aircraft or its contents. The U.S. Environmental Protection Agency has indicated[11] that it will allow halon 1301 to be installed in new systems designed for protecting class D cargo areas, but international pressure is extremely high to phase out all uses of the chemical because of its high potential for depleting stratospheric ozone. None of the available alternatives to halon 1301 perform as well, and in the event of an inadvertent discharge, collateral damage could be significant. Physical damage to cargo, injury or death to animals, and difficulty in cleaning up are the main concerns. Injury can be caused by the high momentum and low temperature of the discharging agent jet, by asphyxiation, or by toxic reaction to the chemical. Toxic reaction due to cardiac sensitization levels below those which lead to asphyxiation are a real concern for some of the alternative gases. For any suppression system, then, discharge of an agent due to a false-positive detection of a fire carries with it a severe penalty for the air carrier.

Once the fire suppression system has been activated, the flight is diverted to the nearest suitable airport. This may be up to three hours away, and could be in an area unfamiliar to the pilot or at an airport with minimal facilities causing potential for additional hazards to the aircraft and occupants. Unfamiliarity and lack of facilities provide added risk in addition to those resulting from an emergency evacuation. In the event of a real fire, the risks associated with this chain of events are obviously acceptable considering the alternative to not detecting the fire. But the consequences of a detector mistakenly classifying a nuisance signal as a fire threat are costly and dangerous.

The primary design goal for an aircraft cargo area fire detector is that it always respond positively to a real fire and always respond negatively to a non-threatening condition. Redundancy is used in the design of aircraft fire detection systems to reduce the chance that an alarm is due to a detector fault. Even so, false alarms occur at a rate far greater than the number of actual fires, with estimates of ratios ranging between 10:1 and 500:1. Interestingly, the one U.S. Air Force cargo aircraft that is protected with halon 1301 (the C5) has no reported incidents of false discharges. This is likely due to the accessibility of the cargo area in flight, which permits a crew member to investigate the area and to verify that the alarm is not false prior to the discharge of the halon. This is in contrast to commercial class C and D cargo spaces, where little is known about the state of the cargo environment during the range of normal operating conditions, and about how conditions are perturbed in the very early stages of a fire. Standard methods do not currently exist for evaluating the response of detection systems to realistic early fire and nuisance stimuli, nor for evaluating detection systems that rely on new sensing technologies or combinations of sensors that have the potential for reducing the nuisance-signal-to-actual-fire ratio.

Discussion

The discussion sessions were focused on answering the following questions as they apply to aircraft cargo areas: (i) What conditions produced by a nascent fire can be sensed to warn of a threatening situation? (ii) In what time-frame must a response strategy be formulated, and what are the consequences of a false-positive? (iii) What physical environments or activities are likely to lead to a false-positive? (iv) What test methods are required to evaluate the immunity of fire detection systems to false-positives? (v) What are the action-items for the group, and who should take responsibility for each?

Smoke and particulate, temperature, major combustion gases (CO_2, CO, O_2, H_2O), relative humidity, minor gases (e.g., HCl), thermal radiation, and acoustic emission were mentioned as candidates to sense the presence of a fire. Combinations of smoke (ionization) plus CO and/or temperature, or smoke (photoelectric) and temperature were suggested as means to increase selectivity. A cargo area temperature readout in the cockpit was thought to be a good back-up indication.

The minimum time from the onset of a fire to its positive identification is stipulated in the FAR[7] to be one minute. The group felt, however, that the actual window to ensure safety depends upon the sensitivity of the detector and the event which triggers the fire. Tied into the equation is what additional information may be available to confirm the initial indication of a fire. The consequences of inappropriately classifying a non-fire state as a fire were identified to be needless diversion, emergency landings, possible evacuation injuries, reduced confidence in the system, and release of halon 1301 to the atmosphere.

The sources of false-positive indications depend upon the sensor. For smoke detectors, condensation was given as the leading nuisance. When on the ground, sand and dust, as well as particulate matter from engine exhausts, can lead to false alarms,. Gas detectors (primarily on the ground) are also susceptible to exhaust emissions (CO, CO_2) from auxiliary power units and taxiing aircraft. Livestock emit moisture, CO_2, CO, and CH_4. Fruits, vegetables and flowers emit water vapor and are often treated just prior to the closing of the cargo doors, producing condensation which can trigger a smoke or gas detector.

The success of a test method for background nuisance sources is tied to how well one is able to evaluate the response of the detector to a simulated fire. A considerable effort is required to make sure that the fire used to evaluate a detection system corresponds to a realistic threat, that the simulation is equally valid for a range of detection options (e.g., smoke, heat, gas), and that the fire simulation is repeatable. Once a standard fire is defined, such as those used by UL[2] or the European Community[12], then one needs to define the standard non-fire. A better understanding of the environment within the cargo area and a more thorough assessment of the historical causes of false alarms are needed before new test methods can be developed. From anecdotal evidence, moisture is a major source of false alarms; hence, a new test to evaluate the immunity of a detector to condensation is likely to be necessary. The application in class D spaces of detection systems designed for class C cargo areas sometimes requires installing the detector in a recessed pan. A method needs to be devised to account for the change in transport to the sensing element due to the recessed location. The operating software and system logic are an integral part of the fire detection system and need to be certified along with the sensor in a fire and non-fire state.

Actions are required by a number of groups to reduce the number of nuisance alarms from aircraft cargo area fire detection systems. The FAA, NASA, NIST, and UL can all play a positive role, but the direct involvement of the airlines, airframers and fire protection equipment suppliers is required to ensure successful development and implementation of any new test methods or certification procedures. The key items to be addressed are the following: defining realistic fire threats and simulating them; documenting existing aircraft environments; simulating aircraft environments that lead to false alarms; determining requirements of the airline industry in regards to the tolerable rate of nuisance alarms; and examining current operating practices (e.g., the carrying of livestock, or spraying of flowers) as a means to identify opportunities to reduce false alarms.

RECOMMENDATIONS

Recommendations from the workshop are listed below under three categories: general in nature and applying to multiple commercial installations, specific to telecommunications, or specific to aircraft cargo areas. When it is obvious which organizations should take part in implementing the recommendations, they are so indicated.

General

- Assemble available data on the environmental conditions within aircraft cargo areas and critical telecommunication spaces. (users, equipment suppliers)

- Expand capabilities of the NIST FE/DE to simulate common environmental nuisance sources including dust, combustion engine exhaust gases, and relative humidity, and develop protocol to evaluate detection systems exposed to these environments. (NIST, certifying agencies, equipment suppliers, users)

- Develop industry consensus on what constitutes "acceptable" performance for new classes of detection systems. (users, equipment suppliers, certifying agencies)

- Investigate methods for evaluating and certifying proprietary software to ascertain its ability to discriminate a fire from a non-fire state in the presence of nuisance background sources. (certifying agencies, equipment suppliers, users, NIST)

- Develop safe, convenient, and scientifically sound techniques to certify detection systems as installed in the field. (certifying agencies, NIST, users, equipment suppliers)

- Demonstrate ability of computer models to predict the transport of aerosols from a source (fire, suppression action, or natural ventilation system) to the detector and other critical surfaces within a protected space. (NIST, FAA, NASA, NFPA, users, equipment suppliers)

Telecommunications Facilities

- Expand capabilities of NIST FE/DE to simulate nuisance sources found from soldering practices used on central office mainframes, and develop protocol to evaluate detection systems exposed to this environment. (telecommunications industry, NIST, detection equipment suppliers)

- Determine the impact of fire generated aerosols and suppression activities on materials and devices critical to maintaining the dial tone. (telecommunications industry, NIST, agent manufacturers)

Aircraft Cargo Areas

- Compile background data from currently installed fire detectors to establish range of conditions (e.g., estimates of particle loading, temperatures) normally encountered in the non-fire state, identify the major sources of nuisance alarms, and develop instrumentation package to fill in critical data on the non-fire state of aircraft cargo areas, with emphasis on class D. (FAA, NASA, NIST, airlines, airframers, detection equipment suppliers)

- Produce an industry accepted accounting of cargo bay related fire incidents, false alarms, and associated actions and costs. (airlines, airframers, equipment suppliers, FAA)

- Expand capabilities of NIST FE/DE to evaluate the ability of current and emerging sensing technologies to discriminate fires from elevated nuisance background levels. Begin with test methods to simulate relative humidity up to the saturation point and temperatures from 4 °C to 50 °C (40 °F to 122 °F), making use of numerical computations as appropriate. (NIST, FAA, NASA, airframers, airlines)

- Develop aircraft certification methods and allowances for alternative detection methods (e.g., CO, radiation, and combination sensors).

- Develop consensus among the regulators, users, and fire researchers on realistic fire threats to be detected, as specified by fuels, geometry, rates of heat release, and times to detection. (FAA, NASA, NIST, airlines, airframers)

- Develop a methodology to simulate the consensus fires, and establish acceptable limits for run-to-run variation. This should be done in concert with the FAA's ongoing effort to develop standard fires for evaluating alternatives to halon 1301 suppression systems, and should build off the test fires already developed for ground-based applications by UL and the European Community, and the research conducted by NIST and detector manufacturers. Computational methods should be used to support the physical tests in the FAA facility. (FAA, NASA, NIST, airlines, airframers, detection equipment manufacturers)

- Develop and install a continuous temperature monitor for all inaccessible cargo areas to give the status to the pilot in the event of a fire alarm and subsequent suppression actions. The temperature reading alone should not be the basis of determining whether or not a fire is present, but should supplement the ability of the crew to respond to a fire alarm in more effective manner. (detection equipment manufacturers, FAA, airframers, Airline Pilots Association)