# UP–DATE ON AIRBUS FIRE SAFETY RESEARCH AND DEVELOPMENT

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**ABSTRACT**

Air travel is the safest form of transportation since there have been tremendous improvements in aircraft safety.
In addition to the regulatory standards, manufacturers and operators add their own self-imposed safety criteria. These complementary sets of criteria ensure that the aircraft design represents the highest level of safety.
The risk of accidents, which involve fires, cannot be excluded completely, so a continuous enhancement of fire safety in aviation is required.
The aim of safety enhancement activities in Airbus is to anticipate problems before they occur and find solutions that continuously develop the safety of our products. One of Airbus' most valuable sources of information for continuously contributing to safety comes from its in-service fleet. As part of the company's product safety process, teams from Airbus work together with aircraft operators to gather, analyze and follow-up information and data from in-service events. This process is fundamental to enabling Airbus to address safety issues in a proactive way.
This paper reflects the past, the current and in particular the future research and developments related to aircraft fire safety.
Airbus believes that the most effective aircraft safety philosophy is to prevent accidents by anticipating and solving problems before they occur.

## INTRODUCTION

With the predicted increase in world air traffic the risk of an increasing accident rate cannot be excluded thus a continuos improvement in aircraft safety is required.

Cabin safety is one of the most important aspects in designing the interior of new airplanes and of on-going improvements of aircraft already in service as well.
However, it must be pointed out that after crash safety aspects are only the second step in a comprehensive accident prevention design.
The area of active accident prevention bears much more potential for reducing the danger of tragic losses of aircraft and their occupants, which happened in the past.

The present state of the art of aircraft fire safety already represents a high standard. The history of flammability requirements for cabin interior shows that flammability regulations were first adopted in 1947 with a requirement that cabin materials shall not burn greater than 10 cm in a horizontal orientation when exposed at one end to a bunsenburner flame.

The availability of improved fire resistant materials led to permanent upgrading of the flammability regulations.

**Milestones in Fire Safety**

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| 1972 | Bunsenburner | FAR 25.853 | Amdt. 32 |
| 1984 | Seat Cushion Fire Resistance | FAR 25.853 | Amdt. 59 |
| 1986 | Burnthrough Cargo | FAR 25.855 | Amdt. 60 |
| 1986 | Heat Release (65/65) | FAR 25.853 | Amdt. 61 |
| 1988 | Heat Release (100/100) | FAR 25.853 | Amdt. 72 |
| 1988 | Smoke Density | FAR 25.853 | Change 13 |

**AIRBUS Fire Safety Specification**

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|---|---|---|
| 1979 | AIRBUS Test Specification | ATS 1000.001 |
| 1994 | ATS upgrade | ABD 0031 |

In 1979 Airbus established the ATS 1000.001 (Airbus Test Specification) representing an extended in-house version of the FAA regulations with regard to smoke and toxicity requirements.
All Airbus non-metallic materials installed in the pressurized section of the fuselage had to comply with these ATS 1000.001 requirements.
In 1994 the ATS 1000.001 was superseded by the ABD 0031.
The ABD 0031 represents an increased FST standard such as more severe smoke emission limits for all non-metallic interior components.
The ABD 0031 covers additionally all non-metallic structural component parts installed in the pressurized section of the fuselage.
With the move to bigger aircraft the safety regulations developed simultaneously. The first flammability regulations adopted between 1940 and 1960 were applicable to aircraft in the range of 50 to 150 seats. With the increase of aircraft size more and more regulations became effective. This evolution of flammability safety regulations along with general improved and safer aircraft designs led to a significant decrease of the accident rate.
From appr. 15 accidents per Million Flight Hours in 1962 the rate decreased to 1,9 accidents per Million Flight Hours in 1999.
However, recent events have shown that further efforts in fire safety research are required in order to keep reducing the risk of accidents.

## AREAS OF CURRENT AND FUTURE RESEARCH

In the continuing effort to further improve aircraft safety the following activities are currently made to find adequate solutions.

- Evolution on Materials - Fire Safety -
  - Fire Resistance of Materials in Hidden Areas
  - Fuselage Burnthrough Resistance

- Improved Smoke / Fire Detection Systems

- Halon Replacement
  - Water Mist System
  - OBIGGS

- Fuel System Safety

- Alternative to Oxygen on Board

## EVOLUTION ON MATERIALS - FIRE SAFETY –

### Fire Resistance of Materials in Hidden Areas

As a result of the safety regulations fire resistant materials replaced materials that represent a higher risk of ignition and flammability.
However, there are still concerns about such materials installed in hidden or inaccessible areas of the airplanes such as: Electronic compartment, areas behind sidewall linings and above cabin ceiling, areas behind cargo linings.
The objective of the research is to passively reduce the likelihood of an in-flight fire from occurring by developing more stringent fire tests for materials installed in hidden areas and to identify materials that comply with these new fire tests and hence do not propagate during a fire scenario.
The research should lead to a significant reduction of the risk of an in-flight fire.
A second research approach has been initiated by the FAA in order to actively protect these hidden areas by improved fire detection and suppression systems such as OBIGGS and / or a water mist system.
Airbus has undertaken internal research in order to study the risk of hidden fires behind cabin linings. A full-scale test rig composed of sidewall linings, overhead passenger service units, insulation materials, electrical wiring and airconditioning ducting has been set-up. A heating element has been used as an ignition source. The tests have demonstrated that all materials installed in this hidden area did not show any risk of ignition and subsequent propagation.
Further research is being conducted with the French research center CEAT under the leadership of the French Airworthiness Authority DGAC. The objective is to study the flame propagation behavior of non-metallic materials installed in hidden areas by conducting flame propagation tests on the radiant panel test apparatus. This test program was on going at the date of writing of this report.

**Fuselage Burnthrough Resistance**

Fire hardening of the fuselage against burnthrough becomes an important issue in order to prolong a safe environment of the passengers in the event of a post crash fire scenario.
Such an environment is required in order to manage the evacuation safely.
It was shown during fuselage large-scale fire testing that the aluminum skin of a fuselage provides a burnthrough protection of 20 to 60 seconds depending on its thickness. A fuselage constructed of carbon fiber or GLARE material will offer improved burnthrough protection compared to aluminum.
The large-scale test facility consists of a steel made fuselage rig with a length of 6 m and a diameter of 5.6 m. It has a lateral cut-out of 2 m x 3 m which can be mocked-up with an aluminum skin, primary insulation blankets, interior linings and floor panels.
Devices are provided in order to monitor temperature, heat flux, smoke-, toxicity emission and burnthrough locations and times. A large fire pan filled with kerosene and located underneath the test rig serves as a fire source.

**GLARE**

A new glass fiber / epoxy composite, called GLARE, will be used for much of the upper half of the fuselage skin of the Airbus A380. GLARE is a hybrid material composed of alternating layers of four or more thin aluminum sheets and glassfiber reinforced bond films. The material thickness can be varied by adding sheets to match local property requirements. It offers 15 – 30 % weight saving over aluminum, significant resistant to fatigue properties and excellent fire resistance.
A forthcoming regulation will require that thermal/acoustic insulation, if installed next to the skin in the lower half of the fuselage, be a fire barrier and resistant to burnthrough from fires external to the fuselage caused by the ignition of fuel spilled from fractured tanks.
A significant number of comments were made concerning the application of this burnthrough requirement to the lower half and not around the entire fuselage. It would degrade the effectiveness of this safety regulation.
Airbus is setting the passenger safety standard by protecting the entire fuselage of the A380 against burnthrough. Much of the upper half of the fuselage is protected by GLARE skin material showing excellent burnthrough protection capabilities and the lower portion by the regulatory burnthrough resistant insulation blankets.

## SMOKE / FIRE DETECTION SYSTEMS

Aircraft fire detection systems in airplanes are based on the smoke detection principle. Smoke detectors are installed e.g. in the cargo compartment ceiling. The false alarm rate on commercial aircraft is unacceptable high. The result of such false alarms is aircraft turnbacks, land as soon as possible and AOG (Aircraft On Ground) scenarios.
Detectors are critical to the overall effectiveness of the system, providing early warning and characterization of the fire hazard. A large variety of detectors are commercially available providing a degree of pre-ignition warning and fire hazard identification through the monitoring of either individual or combined combustion characteristics such as: smoke, heat, light and thermal imaging.
Current research activities are concentrating on the development of false - alarm - free detection concepts, focusing on multiple sensors, computer aided signal analysis and video camera aided fire and / or smoke indication especially in cargo compartment.
New multi criteria smoke detection systems will be used in Airbus A380 cargo compartments. These systems are capable to enhance the immunity of false alarms by the generation of multiple detection data and the subsequent data processing using a multicriteria detection logic.

The generation of data includes the principle of optical measurement of smoke density, the information on the type of aerosol and the evaluation of environmental conditions.
The multicriteria detection logic uses internal and external compensation functions and provides finally a status on the situation.

## HALON REPLACEMENT

Fire suppression agents based on Halons are banned in accordance with the Montreal Protocol since they deplete the ozone layer.
Current research is focussing on the development of Halon replacements and on fire suppression systems that uses different technologies such as OBIGGS and / or water mist systems.
Future environmental friendly fire suppression agents should have the same fire suppression behavior than the Halons. Further significant research goals are that new agents should have no toxic repercussions on passengers, maintain visibility and no harmful impact on the ozone layer combined with a no global warming effect.
Although industry and research facilities have spent a lot of efforts to replace the current Halon products, no adequate agent for the commercial aircraft cargo compartment fire suppression systems has been found yet.
Further research is being conducted in order to find alternative fire suppression systems such as water mist and on-board inert gas generating systems called OBIGGS or a combination of both.

### Water Mist System

Tests have demonstrated that the application of a water mist to a cabin fire during a post-crash fuel fire scenario reduced the temperature around the fire to a survivable level and delayed flashover. It has also been concluded that the time available to evacuate an aircraft under such circumstances could be increased by up to 3 minutes.
Having established the benefits, which could be derived from such a system Boeing and Airbus independently conducted studies to highlight any possible disbenefits resulting from a water mist system. After studying advantages / disadvantages the Authorities concluded that the cost per life to be saved was unacceptable high and consequently did not proceed with legislation.
Even with the progress, which has been made in the further development of the system it, is unlikely that the disbenefits (weight, risk of short-circuiting, etc.) will be easily overcome. Therefor water mist systems will not be considered for cabin use the industry attention has focused upon water mist as a halon replacement for cargo and engine fire suppression. A study on the introduction of a water mist system in the cargo compartment of a large high capacity aircraft revealed that the weight increase would be unacceptable high. Weight, cost and safety issues remain a barrier to the introduction of water mist systems.

### OBIGGS – On-Board Inert Gas Generating System

The objective of the research on OBIGGS is to apply a system technology based on gas separation membranes, which separate an incoming stream of air into two exit streams with the composition of one major stream being nitrogen enriched air (NEA) used for inerting applications in cargo compartments, engines, fuel tanks etc. and a minor stream of oxygen enriched air (OEA).

The system can be fed by the bleed air so that air for separation into NEA and OEA would always be available.
To cope with forthcoming long-range operational requirements a technology that combines both the water mist system with OBIGGS is currently under study. The fire suppression capability of the water mist will be used for the initial fire knockdown.
It is immediately available after fire detection and is environmentally friendly. As second step the OBIGGS would release the nitrogen-enriched air into the cargo compartment to ensure long time inerting.

## FUEL SYSTEM SAFETY

Following the B747 TWA center wing tank explosion in 1996, the National Transportation Safety Board (NTSB) in the United States made recommendations to enhance the already good safety record of aircraft fuel systems worldwide. Subsequently the FAA and JAA introduced new requirements relative to the prevention of fuel tank explosions.
An exhaustive design review of the fuel systems installed on the various aircraft types led to the conclusions that the design of the fuel tank systems used on Airbus aircraft remains in general valid and functional throughout the aircraft life. However, the FAA announced to issue a Notice of Proposed Rulemaking (NPRM) with the objective to require an inerting system for heated center wing tanks based on a study, which showed that the technology for nitrogen inerting to reduce the oxygen concentration to less than 12% is practical and cost effective.
Airbus has undertaken major activities related to fuel tank ignition prevention. Most of Airbus modifications addressing ignition sources were developed as part of Continued Airworthiness Process prior to the new EASA and FAA regulations. The EASA considers that Airbus has shown compliance with FAA's SFAR 88 and JAA's INT/POL 25/12 for all fuel tanks by the existing design and the identified modifications and actions.
Airbus is investigating the feasibility and benefits of a Flammability Reduction System (FRS) as an additional layer of protection on top of existing ignition risk mitigation. Airbus and FAA agreed to launch a joint test initiative on an A320 flight test aircraft using the FAA developed Nitrogen Inerting System.
Nitrogen inerting is a process where inert gas is introduced into the ullage (volume within fuel tank not occupied with liquid) of a fuel tank so the oxygen content of the ullage is reduced to a point where ignition and subsequent combustion is precluded.
The testing phase included ground and flight testing exploring system performance over a range of fuel quantities in the tanks, climb and descent rates and different operational configurations of the On-Board Inert Gas Generation System (OBIGGS). The tests have demonstrated the functionality of the system. No major abnormal system operation was observed during different test phases and no significant impact can be observed on the Engine Bleed Air System that feeds the OBIGGS.
Even with the fitment of this system, the ignition risk mitigation modifications agreed with the EASA will be required.

## ALTERNATIVE TO OXYGEN ON-BOARD

Oxygen systems presently used on transport aircraft include chemical generated or gaseous oxygen for use in the event of a sudden de - pressurization.
Gaseous oxygen oxygen systems require significant safety precautions on-board the aircraft and on ground during maintenance and refilling activities.

The research objectives for alternative oxygen systems are to reduce or eliminate the quantity of gaseous oxygen or chemical generators.
A technology that shows promising results so far is an On Board Oxygen Generating System ( OBOGS ).
OBOGS provides the ability to generate and deliver "on-line" oxygen high flow enriched breathing gas to aircraft occupants, through utilization of a pressure swing adsorption molecular sieve oxygen concentrator.
This technology is based on a gas separation concept that utilizes a preference adsorption medium "Zeolithe" that retains nitrogen molecules and allows molecules of oxygen and remaining inert gases (primarily argon) to pass through, thus providing an oxygen enriched breathing gas.
The pressure swing system principle consists of e.g. 3 separate concentrators, cycled sequentially for the production of oxygen.
Air is passed through concentrator 1, which adsorbs the Nitrogen, thus producing gas with a high oxygen concentration. When this concentrator becomes saturated and no longer capable of sufficiently filtering Nitrogen it is switched off and the adsorbed Nitrogen is vented regenerating the concentrator. During this flushing cycle the second generator is producing oxygen, and so on.
A second OBOGS technology is based on the ceramic membrane principle. It uses the catalytic properties of the surface of ceramic material that ionize and then separate the oxygen from air. The produced oxygen does have a high concentration of 99,9 %. The system is capable of refilling the flight crew oxygen cylinders and / or cylinders from the passenger gaseous system during ground and flight operation in the event of a pressure drop inside the oxygen cylinders.

## CONCLUSIONS

Fire safety is a major concern in air traffic. In addition to the regulatory requirements the airframe manufacturers and operators realized supplementary safety criteria in aircraft design. The result of these efforts is that commercial air traffic is the safest transportation mode. Regulatory authorities, airframe manufacturers and operators are committed to further improve safety.

There are significant factors outside the aircraft design, which affect safety as well.
These include communication of knowledge and learning, regulation and regulatory oversight, level of flight operation and maintenance procedures, air traffic management and infrastructures.
Any enhancement in flammability standards to improve the survivability of occupants during an in-flight or post-crash fire scenario requires studies of its feasibility and benefits.
An assessment of the costs of each potential solution needs to be provided. Specific industrial criteria from the airframe manufacturer and operational requirements from the airlines need to be considered if material and design changes will be realized.
During this exercise it is substantial that airframe manufacturers, airlines, regulatory authorities and suppliers work together across national boundaries.