Use of Water Mist and Nitrogen for Cargo Hold Fire Protection
Results of the R&T Project FIREDETEX

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Executive Summary

This paper gives an overview on the FIREDETEX project, which dealt with the aspects of fire detection and fire extinguishing on board aircraft. FIREDETEX (New Fire/Smoke Detection and Fire Extinguishing Systems for Aircraft Applications) was an R&T project co-funded by the European Commission under the leadership of Airbus. The project had a duration of 3 ¼ years and was completed in April 2003.

In the course of the project a fire suppression system was tested successfully under full-scale conditions against the Minimum Performance Standard (MPS) for Aircraft Cargo Compartment Built-In Fire Suppression Systems established by the IASFPWG (International Aircraft Systems Fire Protection Working Group) under the leadership of the US Federal Aviation Administration.

The system used water mist as fire knock-down agent and nitrogen for long-term fire suppression purposes. The water mist was generated by single fluid nozzles - the nitrogen was provided by an OBIGGS (On-Board Inert Gas Generating System).

The FIREDETEX fire suppression system was capable of suppressing all kinds of fire as stated in the MPS and has shown its potential to replace today's Halon cargo fire protection systems in future.
The results achieved with the new fire suppression system are encouraging and the use of water mist and nitrogen as fire suppressants for a cargo fire protection system should be considered further on as potential Halon replacement.

Scope of the programme

FIREDETEX was concerned with the development of new means for early and reliable fire warning and with the development of an environmentally friendly fire suppression system for use in aircraft cargo holds.
However this paper only addresses the fire suppression part of the project.

Motivation for the project

The technology used today for aircraft cargo compartment fire extinguishing applications is based on Halon. Speaking with the voice of an engineer, Halon is the first choice fire suppressant to protect the aircraft's cargo hold. The downside of Halon is that it belongs to the substances that contribute significantly to the depletion of the Earth's ozone layer if released to atmosphere.

Due to their negative effects on the environment, developed countries have banned production of Halons since 1994 with signing the Montreal Protocol Treaty. Following the Montreal Protocol the US Environmental Protection Agency has established regulations that affect purchase and use of Halons, and in Europe the European Union has already banned the installation of Halon systems. Furthermore - effective from 01 January 2004 - all Halon based systems had to be decommissioned in Europe.

However regulatory authorities have allowed the further use of Halons in aviation per exceptional law. The so-called critical use exemption restricts the quantity of Halon to those uses where an alternative is not yet available - but the goal is to reduce and eliminate the critical uses as soon as alternatives become available.

Suppression Concept

Extensive research has been conducted to find a gaseous drop-in replacement for Halon 1301, but until to date no sustainable and suitable agent has been identified so far.

The stringent environmental requirements, which a future fire suppression agent must meet, has put water mist and air separation technology into the game.
Since almost every proposed gaseous replacement agent has failed so far to cope with the requirements either because of human or environmental toxicity and/or agent mass, the FIREDETEX consortium has investigated the benefits of a combined water mist/nitrogen fire suppression system.

System description

The system tested during the course of the project used water mist as initial fire suppressant, whereas generated nitrogen was utilized for long-term fire suppression.

Upon first indication of a fire the water mist system was immediately activated to knock down the fire. Parallel to the activation of the water mist system an On-Board Inert Gas Generating System (OBIGGS) was activated as well. The OBIGG system is based on air separation technology using hollow fiber membranes. It separates an incoming airflow into two output flows – one enriched with nitrogen and one with oxygen (fig. 1).

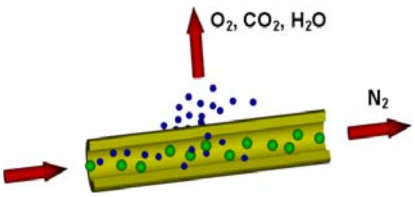

Fig. 1. *OBIGGS Principle*

The Nitrogen Enriched Air (NEA) was directed into the test cell to build up a suppression effective atmosphere.

The use of water mist during the first minutes of the suppression process was necessary to "buy" the OBIGGS time to decrease the oxygen concentration inside the test cell to a suppression effective amount. Therefore the water mist system remained in activation mode until an adequate level of oxygen was reached to provide the fire suppressant sought.

The water mist system was divided into three zones whereas each zone comprised a certain number of water mist nozzles. The reason for this was to minimize the water consumption during the suppression process. The zonal layout allowed to activate only those nozzles (zone) in the affected area of the test compartment instead of flooding it completely.

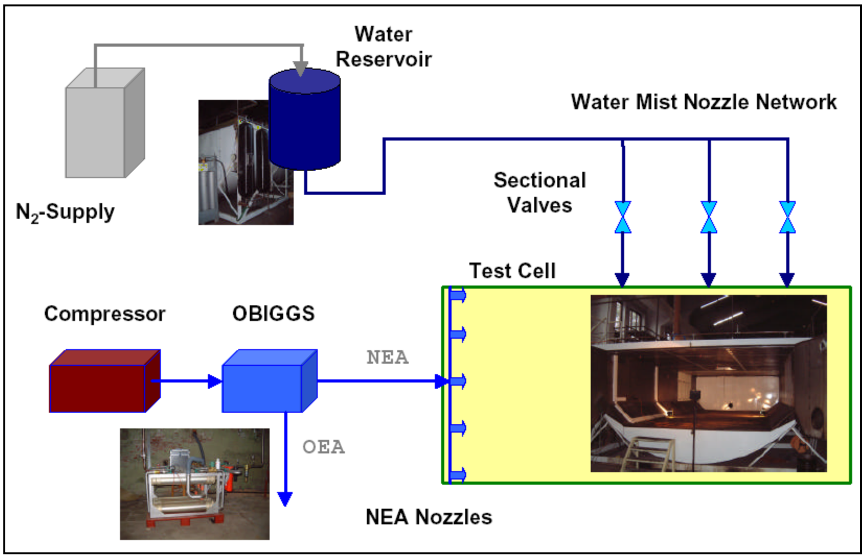

Figure 2. *Test Set-up*

In order to realize a zonal layout a detection system was required that was able to detect and to locate the position of the fire. The FIREDETEX solution for such an intelligent detection device was a Distributed Temperature Sensor (DTS) using a fiber optical wire.

Test Set-up

Figure 2 shows the simplified test set-up for the MPS fire trials. The upper part of the figure shows the water reservoir and the distribution network of the water mist system. The water mist system was operated at a pressure of about 12 bar. A battery of bottled nitrogen was used to generate the pressure. The lower part of the figure shows the configuration for NEA generation. The OBIGGS was fed with pressurized air provided by a compressor. The Nitrogen Enriched Air was distributed via 5 nozzles into the test rig to decrease the oxygen concentration.

For taking the temperature, type K thermocouples were installed along the ceiling and at the sidewalls of the test rig. Furthermore the test rig was equipped with several oxygen probes in order to monitor the development of the oxygen concentration.

System Testing

To assess and verify the suppression capabilities of the system it had to be tested against the Minimum Performance Standard established by the International Aircraft Systems Fire Protection Working Group under the leadership of the US Federal Aviation Administration. The MPS defines four fire scenarios, which any new fire extinguishing system must successfully suppress to meet the requirements stated in the MPS.

According to FAA requirements all tests have been performed in a test cell having a volume of about $56m^3$. The cross section of the Firedetex test article corresponded to that of a lower deck cargo compartment of an Airbus Long Range aircraft.

In the following two of the MPS tests are briefly illustrated.

Figure 3 shows the test set-up for the bulk load fire test. For this test the test cell had to be equipped with card-board boxes filled with shredded office paper.

Figure 3. *Bulk-Load Test*

Figure 4 gives an impression of an open surface fire, which produces temperatures of up to 1000°C. For this test about 1.9 litres of Jet A fuel were used as fire load.

Figure 4. *Open Surface Fire Test*

Test Evaluation

Figure 5 shows a typical chart of a MPS bulk load fire test. When looking at figure 5 it should to be considered that, according to the MPS test protocol, it was not allowed to activate the suppression system before t_2.
The MPS states that after ignition of the fire first a temperature of 93 °C has to be reached (t_1). One minute after t_1 – at t_2 – one is allowed to activate the suppression system. The following 2 minutes (until t_3) are essential for the suppression process. Within these two minutes the system has to contain the fire because after t_3 the maximum measured temperature and the temperature-time interval are determined and compared to the MPS acceptance criteria.
For the bulk load fire test for example the maximum temperature after t_3 shall not exceed 382°C (720°F).

Figure 5 also illustrates the effectiveness of the water mist and the interaction between the detection and the water mist system. The red curve shows the maximum temperature measured during the test, the blue curve gives the water flow and indicates the activation of the water mist system, and the green curve gives the values for the oxygen concentration.

Every time the temperature increased the water mist system was activated based on DTS signals leading to a sudden drop of temperatures. After the fifths activation all temperatures were well maintained below 100 °C.

The chart also shows the decline of the oxygen concentration inside the test compartment due to the Nitrogen Enriched Air delivered by the OBIGGS. Within 9 minutes after system activation the OBIGGS brought down the oxygen concentration (green curve) from 21% by volume to 12% by volume. This oxygen concentration is commonly considered as a level, which ensures safe fire suppression.

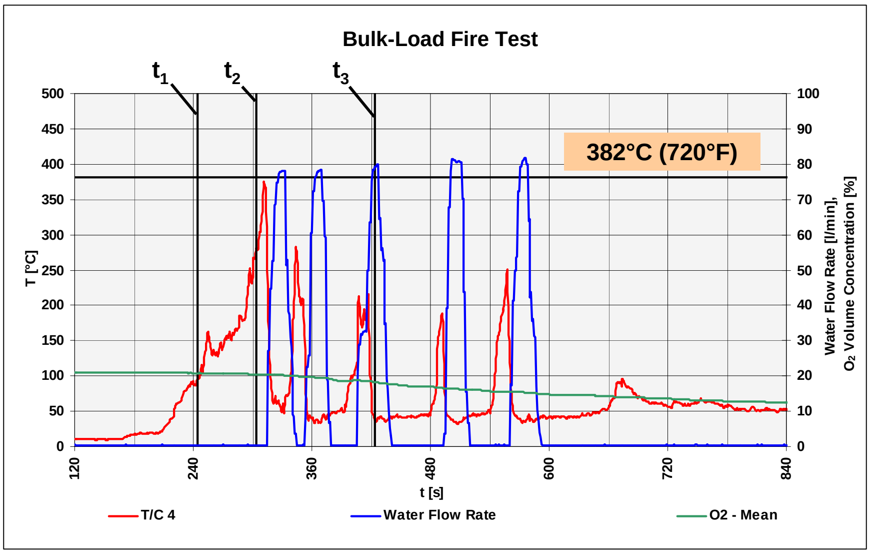

Figure 5. *Bulk-Load Fire Test*

Although the system was able to suppress all kinds of MPS fires the water consumption has to be optimized. The water consumption during the MPS bulk load and the exploding aerosol can test was about 260 liter for each test. The water consumption during the open surface fire and the containerized fire tests was around 145 liter.

Reasons for the high water consumption were identified and the Firedetex consortium is convinced that the water consumption can be reduced considerably without lowering the suppression performance of the system.

Conclusion

So far the aircraft is covered under the critical use of Halon but we will have to be prepared for the future after Halon.

Alternative technologies with low climate impact will become more and more available. Therefore it is most likely that regulatory pressure will increase.

The investigated system offers an enormous potential for further research. Especially the combination of water mist and on board generated nitrogen is of great importance for aircraft cargo compartment fire protection application because the extinguishing performance related to the system weight seems to be attractive.

The test results have provided valuable knowledge to the project consortium regarding the feasibility of an environmentally friendly water mist/nitrogen based fire extinguishing system.

The system was capable of suppressing all kinds of fire as specified in the MPS and is a promising alternative to today's Halon based systems.
Research should go on to come to a system that will fulfill future international agreements and laws and that will comply with the specific a/c requirements.