Environmental-Friendly Fire Suppression System for Cargo using Innovative Green Technology

EFFICIENT

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Fire suppression and explosion protection have conventionally used halon as the extinguishing agent due to favourable properties like being electrically non-conductive, dissipate rapidly without residue, safe for limited human exposure, and are extremely efficient in extinguishing most types of fires. However, halon is accompanied by high levels of Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). In 1994, The Montreal Protocol (MOP) [1] issued a ban on the production of substances that deplete the ozone to reduce the consumption of these substances. Current estimates are that global halon availability will deplete by the year 2035. This paper discusses the substitutes for halons based on ozone depletion potential, global warming potential, toxicity, flammability, and exposure potential. Nitrogen was selected as the fire suppressing agent based on the literature review and is followed up by computational fluid dynamics (CFD) studies accompanied by a small-scale cup burner test as described in BS ISO 14520 [2] to identify the extinguishing concentration.

The EFFICIENT project was part of the Clean Sky 2 initiative that has developed a potential fire suppression technology for eventual application in the cargo-cabin architecture of existing and next generation aircraft. The objective of the study is to identify the extinguishing criteria for nitrogen which will replace Halon 1301 and be able to qualify and replicate the FAA Minimum Performance Standard (MPS) [3]. A wide body aircraft cargo compartment of a simulator has been constructed and equipped with the appropriate instrumentation systems. Four test scenarios of Bulk-Load and Containerised-Load Fire Test, Surface Burning Test and Aerosol Can Explosion Test were replicated and conducted in the simulator according to standards mentioned in the FAA standard. The aim was to establish and test the EFFICIENT Fire Knockdown System (EFKS), which is the system responsible for the initial tackling of the fire. This will also be capable of operating under a range of environmental conditions (-40°C to +55°C) to ensure the established agent discharge rate at representative flight operating temperature range. The pass criteria are listed in Table 1.

Table 1 – Acceptance criteria according to the MPS [3]

Fire Scenario	Maximum Temp. °F (°C)	Maximum Pressure psi (kPa)	Maximum Temp-Time Area °F-min. (°C-min.)	Comments
Bulk Load	710 (377)	Not Applicable	9850 (4974)	Use the data that are between 2 and 30 minutes after suppression system activation. See figure 11.
Containerized Load	650 (343)	Not Applicable	14520 (7569)	Use the data that are between 2 and 30 minutes after suppression system activation. See figure 11.
Surface Fire	560 (293)	Not Applicable	1190 (608)	Use the data that are between 2 and 5 minutes after suppression system activation.
Aerosol Can Explosion Simulation	Not Applicable	0.0	Not Applicable	There shall be no evidence of an explosion. No enhancement of explosion at below inert concentrations.

CFD simulations revealed that an overall concentration of 40% nitrogen has to be reached corresponding to 12% oxygen concentration to suppress a fire source in an enclosure. A series of thermocouples have been installed on the demonstrator to monitor to capture the trends of the internal temperature during the suppression agent release. The cargo load to be burned was simulated with a specified size of cardboard boxes filled with 1.1kg of clean shredded paper each. Automated controls have been implemented, so that all the required actions - such as ignition and agent release - follow the specified sequence and ensure safe execution of the experiments without any exposure of Staff members to fire environment. The CFD simulations were verified against the experimental results.

The four MPS test scenarios have been completed. The Surface burning, Containerised load, Bulk Load and Aerosol explosion test cases were performed and checked against the acceptance criteria of the standard, using compressed nitrogen. The surface burning tests showed high consistency in terms of fire temperature profiles in all the test runs. Containerised and bulk load test runs had some randomness but overall, they passed the acceptance criteria. Finally, the aerosol explosion scenario was performed without any evidence of explosion and the pressure increase due to the high-pressure mist discharge did not exceed the value recorded at the baseline test (2.5 mbar). All 4 test scenarios have passed the MPS criteria, proving that compressed nitrogen could be considered as an alternative agent suitable for aircraft cargo compartment fire suppression.

References:

[1] *United States Congress Senate Committee on Foreign Relations.* "Amendment To the Montreal Protocol on Substances That Deplete the Ozone Layer": Report (to Accompany Treaty Doc. 103-9). [Washington, D.C.]: [U.S. G.P.O.], 1993.

[2] BS ISO 14520 Annex B. *Determination of flame-extinguishing concentration of gaseous extinguishants by the cup burner method*. BS ISO 14520 -Part 1, "Gaseous fire-extinguishing systems - Physical properties and system design," British Standards Institution, 2006.

[3] Reinhardt, J. W. (2003) 'Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems', (April). Available at: *http://www.fire.tc.faa.gov/pdf/TC-TN12-11.pdf*.

Figure 1 – Cargo hull simulator

Figure 2 – Cargo hull simulator interior

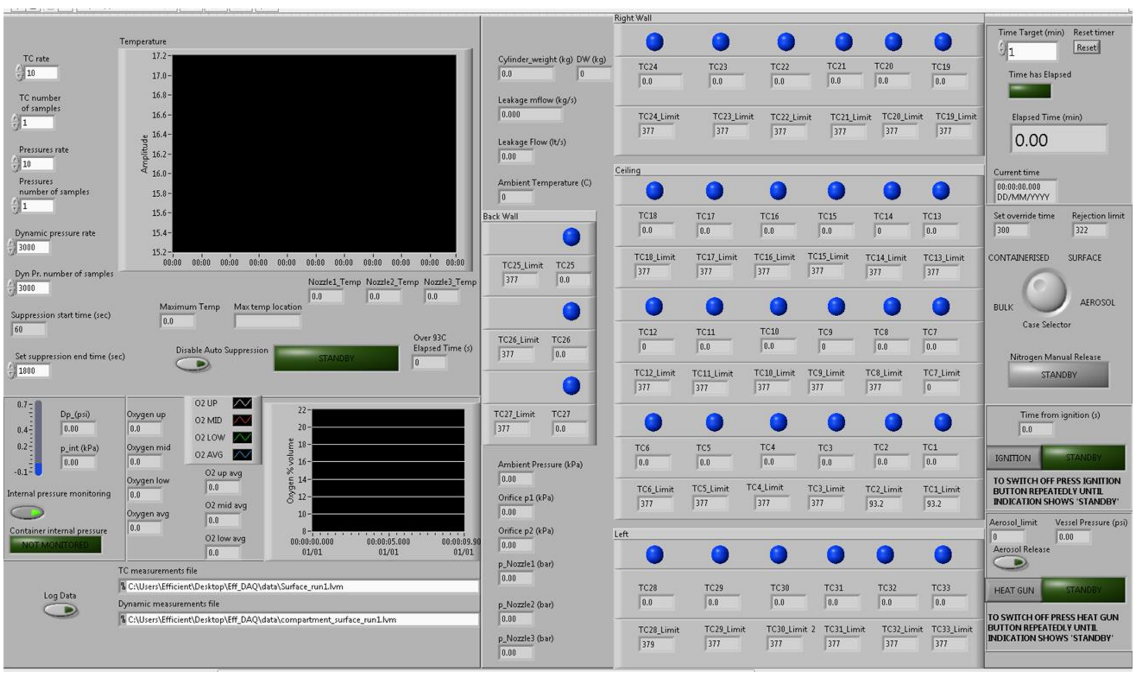

Figure 3 – User interface for the experiments

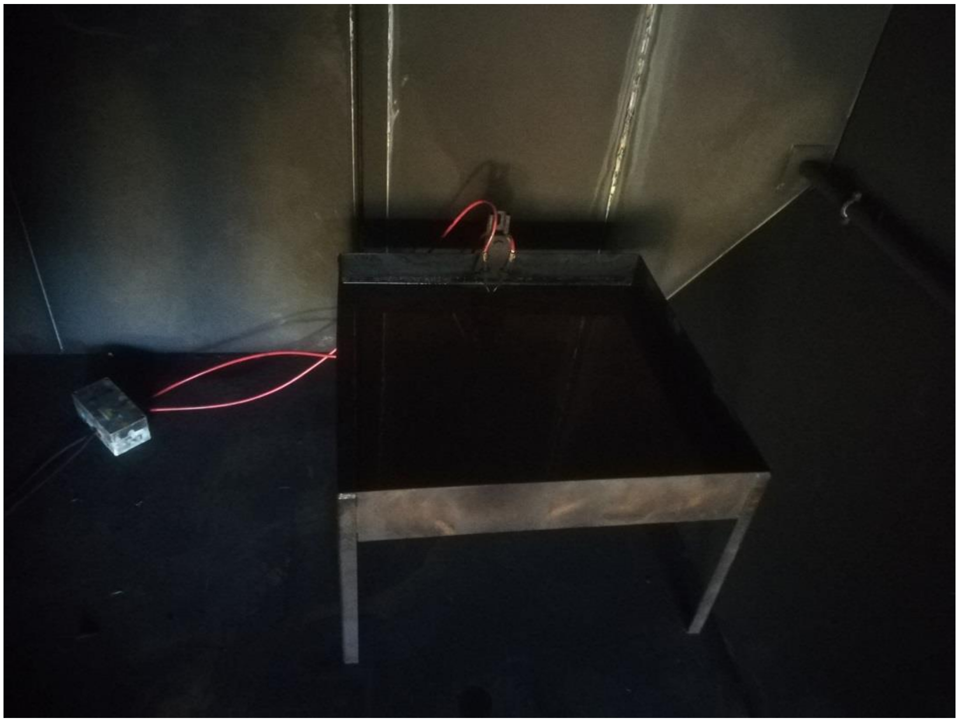

Figure 4 – Surface burning scenario arrangement

Figure 5 – Containerised load scenario arrangement

Figure 6 – Bulk load scenario arrangement

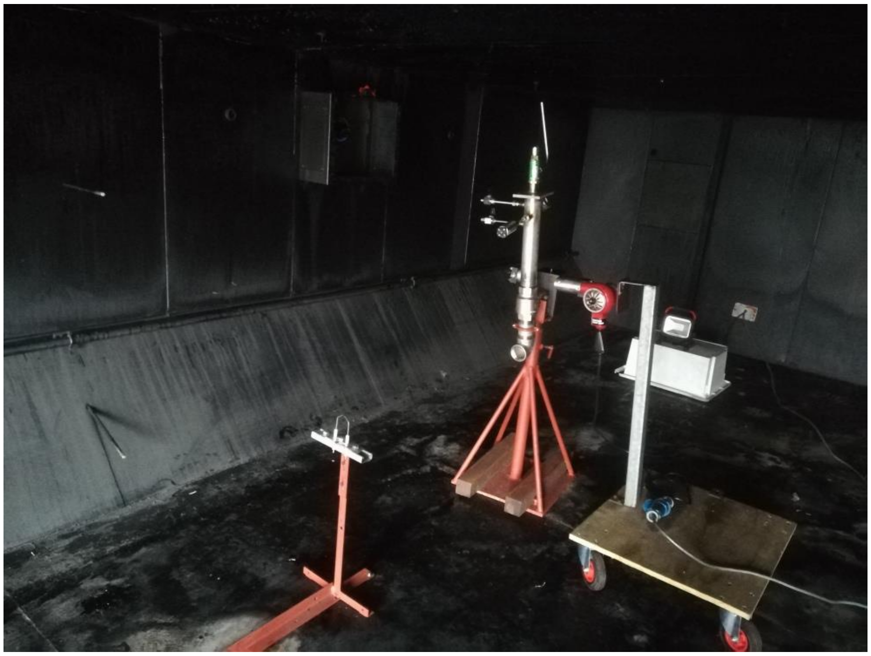

Figure 7 – Aerosol explosion scenario arrangement

Figure 8 – Recycling of unburnt paper and cardboard