Prediction of Fire Extinguishing Agent Concentration in Engine Core Compartment

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The need to design an effective fire extinguishing system arises whenever a new fire extinguishing agent is selected and/or new engines or auxiliary power system (APS) will be in service for an aircraft. For airplane safety, any possibility of fire inside engine core and APS compartments should be quickly and reliably prevented before eruption of fire. One current effective preventive scheme is to spread fire extinguishing agent inside compartment as quickly as possible before jet fuel or oil leaks can catch fire on hot surfaces. More specifically, fire extinguishing agent should not only be delivered quickly to engine compartment, but should also be spread efficiently such that resulting concentration histories satisfy the FAA's certification requirements. Fire extinguishing agent is discharged from storage bottles through distribution pipes and finally injected into engine core compartment using multiple nozzles with different sizes. The concentration distribution inside a compartment varies greatly depending on installation (locations, injection directions) of injection nozzles. At the present time, the optimum nozzle installation conditions are determined by a series of ground tests that are time-consuming and costly, consuming many bottle of fire extinguishing agent.

In order to design a fire extinguishing system with optimum installation of nozzles, an analytical design tool has been developed within the Boeing Company, considering all important process of a fire extinguishing system, covering from the discharge of fire extinguishing agent from storage bottle, the two-phase flow of agent liquid and vapor along distribution pipe, the injection of two-phase agent using multiple nozzles, the propagation of agent vapor in vented compartment air. The design tool is based on the computational fluid dynamics method of two-phase flow to account for the liquid agent evaporation, the momentum interaction between the gas- and liquid-phases, and the binary diffusion of gaseous agent in vented air stream. An unstructured computational mesh was used to accurately model the complicated engine core compartments geometry.

The tool has been validated by simulating fire extinguishing process of engines and APS during FAA certification tests. The predicted concentration histories at twelve different concentration probe locations inside compartments were evaluated using the certification test data. The comparisons of the predicted and the measured concentration histories for engine and APS test cases will be presented. Also, the comparison of concentration histories at different bottle temperatures of 70 and -65 degree Fahrenheit will be presented for each case. The validation analysis results revealed excellent correlation between the predicted and the test data, demonstrating the validity of the simulation method used in the design tool. The design tool has been used in the preliminary design of fire extinguishing system and as the guide to complement certification tests.