Modelling the Release Rate of Oxygen-Rich Air from Aviation Fuel within Aircraft Fuel Tanks

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ABSTRACT

The flammability envelope within aircraft fuel tanks and the environmental factors that affect it have driven development of flammability reduction methods (FRM's) in commercial aviation. An important factor known to influence flammability which has received only limited industry focus is the release of oxygen-rich air from the fuel. Central to an improved understanding and characterisation of this phenomenon and the flammability issues air release presents is a mathematical model, capable of predicting oxygen-rich air release behaviour within fuel tanks. Modelling the fuel's air release behaviour will provide substantive reward by improving the accuracy of fuel tank inerting system performance and tank flammability studies in future aircraft systems design.

In this study mathematical model development has taken a semi-empirical approach. The ullage oxygen concentration within laboratory-scale fuel tanks has been measured in real time over a wide range of conditions. Specifically the effects of fuel agitation, ullage pressure and fuel temperature on the release rate of oxygen-rich air from the fuel, into the tank's ullage, has been examined. Oxygen concentration vs. time data has subsequently been fitted with a multi-parameter, exponential growth model, derived from a first-order differential equation for oxygen release. Through use of its shape parameter the model is able to predict both the air-saturated and supersaturated release conditions encountered within the experiments. Parameter estimates for the rate and time constants of gas release together with release rate values were generated by the model.

This experimental study and mathematical modelling of the data has clearly demonstrated that the rate of air evolution exhibits differing mathematical functions of time, depending upon whether the fuel is in an air-saturated or supersaturated state. It is imperative therefore that any model describing this phenomenon is capable of accommodating this effect. Future work on this subject will look to validate the experimental data and model with flight test data from an Airbus A340 aircraft. If this proves successful the estimated time constants of gas release from the modelling activities will be incorporated in a Fuel Tank Flammability Assessment Model (FTFAM).