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REVIEW OF MODELS FOR SELF-PRESSURIZING PROPELLANT TANK DYNAMICS

The self-pressurized feed system is a type of gas-pressure feed system, where the pressurization working fluid is retained in the liquid state to reduce tank volume. The liquid pressurization working fluid is heated and gasified in the heat exchanger from the hot propellant using a regenerative cooling strategy.

The oxidizer in the case of many hybrid rocket propulsion systems is nitrous oxide. Thermochemically its performance is similar to hydrogen peroxide or nitric acid, but often it is operationally easier to use. The primary reasons are that it is non-toxic, requires little or no thermal control, and is therefore relatively easy to handle. Additionally, nitrous oxide's vapor pressure at standard conditions is high enough that often an external pressurization system is not necessary.

Several scientific groups have developed models for nitrous oxide tank dynamics (see, for example, Whitmore & Chandler [1], Zilliac & Karabeyoglu [2], and Casalino & Pastrone [3]). However, while these models have been managed by these researchers to reproduce their own experimental results they operate conflicting assumptions and it remains unclear which model (if any) can be used for your own system. This uncertainty stems from the fundamental lack of knowledge about what is going on inside a draining self-pressurized propellant tank.

We consider three models: an equilibrium model, a non-equilibrium model similar to Zilliac & Karabeyoglu, and the non-equilibrium model of Casalino & Pastrone.

Equilibrium models for nitrous oxide tanks have been presented by Zakirov & Li, Whitmore & Chandler [1], and Casalino & Pastrone [3]. This model includes heat transfer between the fluid and the walls, which Zakirov & Li included but

Whitmore & Chandler and Casalino & Pastrone did not. The equilibrium model is by far the easiest to implement and solve, with the simplest differential equations and requiring properties only at saturation. Sometimes it accurately predicts the pressure time history, and other times it gives values higher than experimental data show. It cannot capture the initial transient. It does not accurately produce temperature time histories, at least when compared to the small-scale data of Zimmerman.

In a paper by Zilliac & Karabeyoglu [2], a model is presented that builds a level of complexity onto the equilibrium model by allowing the liquid and vapor to be at different temperatures and directly calculating the heat and mass transfer between the phases. This model is the hardest to implement and requires an equation of state in order to calculate properties away from saturation. Solution times are also the longest of the three racy.

In a paper by Casalino & Pastrone [3], two different models for self-pressurizing propellant tank dynamics are presented, in particular: an equilibrium model and "two-phase lumped model". In terms of implementation and solution, the Casalino & Pastrone model is a compromise between the equilibrium and Zilliac & Karabeyoglu models. It has more complex differential equations than the equilibrium model, but only needs properties at saturation and hence does not require a full equation of state.

REFERENCES

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