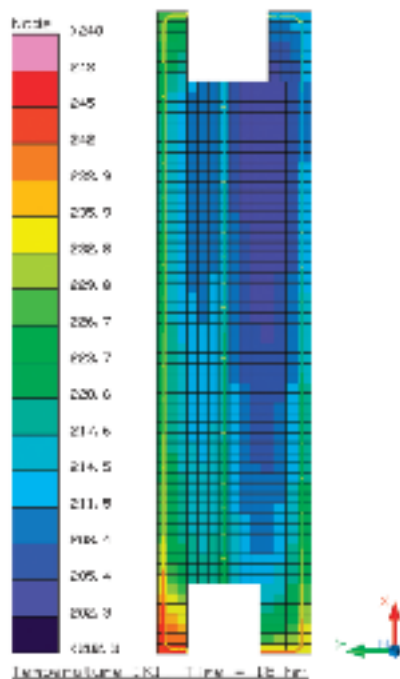


Paragon Stagnating Radiator

Through research and development in radiator design and thermal control system (TCS) fluids, Paragon has worked towards finding lightweight heat rejection solutions for spacecraft that operate with highly variable heat rejection requirements. These systems are not only able to operate throughout widely varying parameters, but they also reduce the number of components resulting in a lighter weight system with fewer failure modes.

Spacecraft Thermal Control System (TCS) design challenges arise when the heat load varies significantly during the course of the mission. One approach for single fluid loop systems to better manage cold/low power regimes is for the radiator to stall, by design, in specific tubes during reduced heat loads. The fluid temperature drop causes an exponential increase in viscosity which can be used to predict stagnation at a given flow rate and fluid inlet temperature. By changing the length of tubes within the radiator, the longest tube will experience the most flow resistance and cool more, which can result in stagnation. This prevents the entire radiator from freezing during periods of



Thermal Desktop® Model:
Environment surrounding test article.

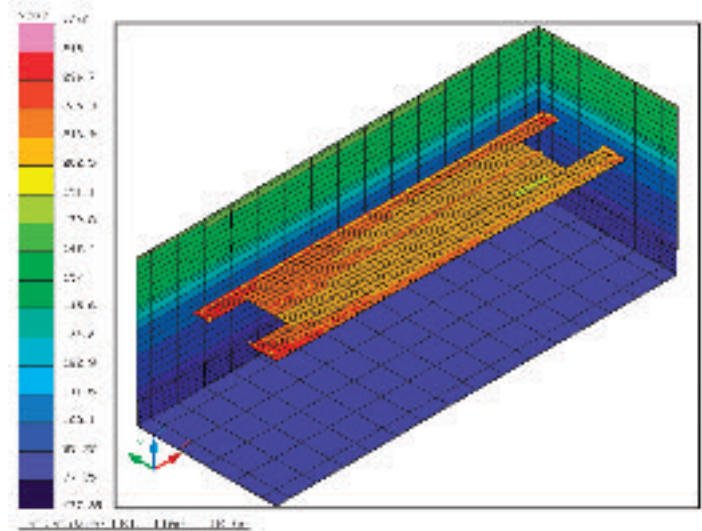


Stagnating radiator sub-scale test article

reduced power. Another option to a stagnating radiator is to design a “stall resistant” radiator with low temperature stalling characteristics and resistance to premature stalling.

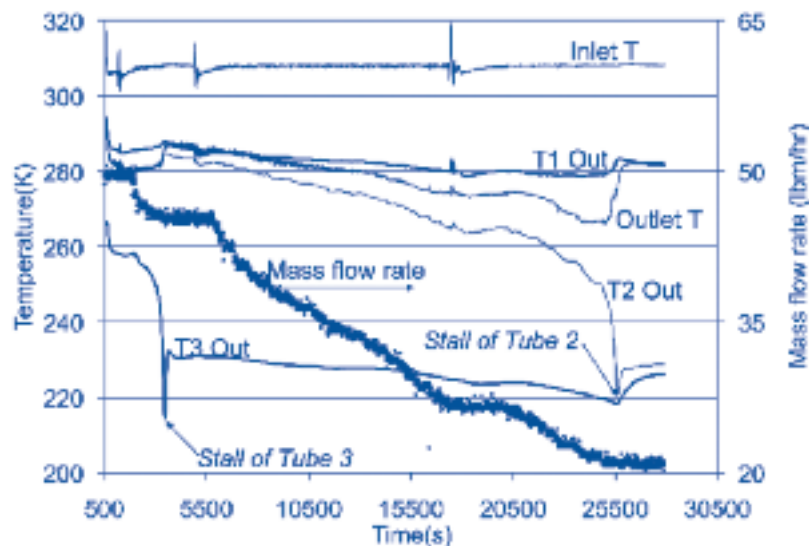
Paragon Space Development Corporation is developing a single-loop, non-toxic, active pumped thermal control design for robust, reliable operation near stagnation regimes as experienced in low power/cold environments. This research uses a fluid called Galden® HT170, manufactured by Solvay Solexis. Galden® HT170 is a non-toxic, non-flammable fluid acceptable for a human-rated spacecraft interior, has an extremely low vapor pressure and does not freeze, but increases in viscosity to a defined ‘pour point’. In addition to the favorable viscosity properties of Galden for a stagnating or stall resistant radiator design, the fluid is non-corrosive, dielectric, and has a low skin, eye, and respiratory hazard rating.

Through multiple NASA Small Business Innovation Research programs (SBIR) as well as through internal research and development funds and radiator design for the Orion program, Paragon has been working to further develop stagnating and stall resistant radiator designs. Three sub-scale test articles have been built and tested in Paragon's Research and Development Lab to further develop modeling capabilities and increase knowledge on how radiators stall and unstall. During testing, tube stagnation has been sequentially controlled in a predictable manner, while collecting data to validate Thermal Desktop® models.



*Thermal Desktop® Model:
Top-down view of facesheet with all tubes flowing.*

Stagnation was also accurately predicted based on the achieved change in fluid temperature along the tube. Further work is being completed on stall resistant designs, and a full scale panel will be tested in a thermal vacuum chamber in late 2009. In addition to radiator design and development, fluid compatibility testing for Galden® HT170 was conducted at nominal temperatures and at extreme (vaporizing) temperatures. Results showed no degradation in the weld joints or tubing test sections and no fluid decomposition was observed. The fluid samples retained their properties showing good compatibility of the fluid with aluminum tubing and welds while operating in temperature regimes similar to a spacecraft thermal control system. Stagnating and stall-resistant radiator technology utilizing Galden® HT170 or other fluids, can be implemented in any spacecraft pumped-loop thermal control system that provides cooling during missions with varying heat rejection requirements.



Data from stagnating radiator test article tested in the R&D Laboratory at Paragon. The three-tube system was sequentially stalled on command as predicted.