NON-PROPRIETARY PROJECT SUMMARY

Purpose of the Research

This project was responsive to NASA SBIR Topic X10.01, specifically, the need for efficient small- to medium-scale hydrogen liquefaction technologies, including domestically produced wet cryogenic turboexpanders. Future NASA missions and facilities will require hydrogen liquefaction systems for spaceport, planetary, and lunar surface operations. A critical part of these systems is the cryogenic turbines, which must be designed for high-speed operation (to obtain high efficiency) and long life, and must be robust against the pressure and momentum excursions and the surface tension effects associated with two-phase flow.

Brief Description of the Research Carried Out

On the Phase I project, we identified and optimized a liquefaction system that produces 5000 gallons/day of liquid hydrogen for spaceport operations. We quantified the benefits of using expansion turbines in the product stream instead of the customary Joule-Thomson throttle. The use of the turbines reduces liquefier input power by 15% or nominally 60 kW for a liquefaction rate of 5000 gallons/day. Five turbine stages are required to efficiently expand the hydrogen over a pressure ratio of 20:1. The turbines utilize an alternator for power recovery and control, and hydrodynamic gas bearings that operate at cryogenic temperatures. These features reduce complexity, reduce input power, and improve reliability as compared to commercial turboexpanders. In addition, we developed designs for the five turbine stages that have over 90% common parts. The exception is the aerodynamic parts, which are optimized for each stage. This approach results in high overall cycle efficiency and low development and production costs.

On the Phase II project, we built and tested a turboalternator capable of operating in hydrogen liquefiers. Upon fabricating the expansion turbine, we conducted detailed performance testing, demonstrating net efficiencies as high as 80%. Furthermore, using our test data we validated our performance models by accurately predicting performance, even at off-design conditions. Finally, we conducted various cryogenic functionality and bearing stability tests to demonstrate the capability of the turboalternator to operate over a wide temperature range.

Research Findings or Results

On this Phase I/II program, Creare built and tested a high-efficiency cryogenic turbine for use in a hydrogen liquefier. Our turbines have the innovative feature of recovering the expansion work through use of an alternator (i.e., turboalternator) instead of dissipating work using a brake wheel. This approach greatly simplifies controls, improves reliability, and reduces system mass and input power.