Cryogenics Research and Engineering Experience

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Abstract

Energy-efficient storage, transfer and use of cryogens and cryogenic propellants on Earth and in space have a direct impact on NASA, government and commercial programs. Research and development on thermal insulation, propellant servicing, cryogenic components, material properties and sensing technologies provides industry, government and research institutions with the cross-cutting technologies to manage low-temperature applications. Under the direction of the Cryogenic Testing Laboratory at Kennedy Space Center, the work experience acquired allowed me to perform research, testing, design and analysis of current and future cryogenic technologies to be applied in several projects.

Objective

Engineering support on research, testing, design and analysis comprises the main task during several work rotations. The use of testing apparatus and equipment along with cryogenic expertise on the laboratory were some of the tools that allowed me to provide engineering support to several projects.

Projects

Cryogenic Propellant Transfer

Summary

As part of the development of the 21st Century Launch Platform, several technologies are being tested and developed to support the next generation of launch vehicles.

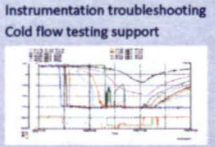
Technologies includes:

- Composite Materials Vehicle Tank
- Multiple Stage Cryogenic Propellant Loading Capabilities
- Automated and Autonomous Propellant Loading Systems

Contributions

Composite Materials Tank Propellant Transfer Testing

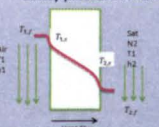
- Data review of thermocouple and pressure transducers
- Analysis of saturation curve based on instrumentation
- Instrumentation troubleshooting
- Cold flow testing support

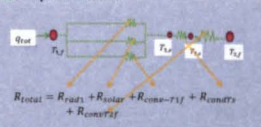


Composite Vehicle Tank, Transfer Line and Data Output

Analysis of vent line system for first stage vehicle tank

- Sizing of vent line for maximum operation and fire contingencies conditions
- Heat transfer analysis considering all possible heat sources on the system
- Safety pressure relief devices implementation



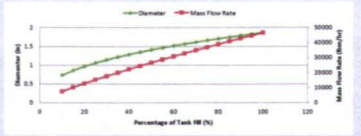


$$R_{total} = R_{rad1} + R_{solar} + R_{cone-t1f} + R_{condTs} + R_{convT2f}$$

Thermal Circuit for First Stage Vehicle Tank

Rupture Disk for Failure Scenarios

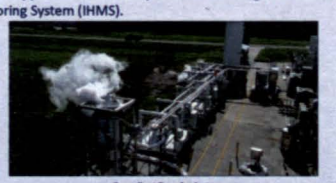
- Analysis of rapid chilldown case: Saturated liquid nitrogen entering the vehicle tank leaves at saturated vapor/superheated gas conditions increasing vehicle tank pressure
- Analysis of rapid boil off case: Saturated liquid nitrogen boils off at different liquid levels in the vehicle tank increasing vehicle tank pressure



Diameter variation with tank level and mass flow rate

Automated Sequence Development for Propellant Transfer

- Sequence developing for chill-down operations of the cryogenic propellant transfer line
- Sequence development of cryogenic pump operations for cryogenic propellant transfer line
- Development of redlines mitigation procedures/sequences: saturation curve, pump cavitation, revert and shutdown sequences.
- Provide support for the development of the Integrated Health Monitoring System (IHMS).



Propellant Transfer System

Camera System for Health Monitoring System

- Camera coordination of all control and remote operating valves integrated into the propellant transfer line
- Assembly, wiring and connection of new control camera for the health monitoring system
- Structural and wind loading analysis of new camera for pole installation

Camera Pole Concept

Cryogenic Materials and Devices

Summary

Materials research and development on low temperature applications provides cryogenic systems the technology stepping stone to improve propellant insulation, conservation and transfer systems. In addition, it opens the possibilities for new low temperature applications.

Contributions

Aerogel Testing

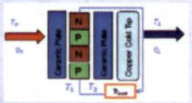
- Cup Cryostat was used to test different samples of Aerogels
- Variations on material density was used under cryogenic temperatures (77K) and ambient pressure
- Thermal Conductivity was calculated for different samples using the one dimensional heat transfer equation assuming homogeneous material and steady state conditions.

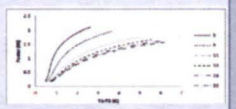
Cup Cryostat

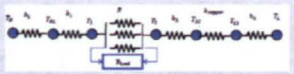
Aerogel Samples

Thermoelectric Modeling

- Power generation at cryogenic temperature
- Application to wasted heat sources
- Application to cryogenic system







Thermoelectric Modeling and Simulation Results

Cryocooler Reactivation, Installation and Testing

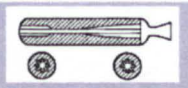
- Familiarize with cryocooler technology.
- Assembly, data acquisition, insulation, piping, pressurization procedure and safety of cryocooler

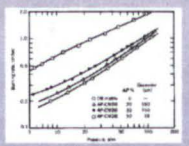
Cryogenic Cooler

Other Propulsion Propellants

Solid Propulsion Program

- Simulate the pressure profile of commercial rockets like Delta IV and Atlas V with the purpose of learning the SPP 8.0 Software
- Modify the grain design, equilibrium module and ballistic module to simulate a test rocket
- Produce all the necessary output to match pressure distribution of test rocket with actual experimental data.





Conceptual Grain Design Thrust Distribution and Burning Rate

What I learned

Skills Gained

- Knowledge on analysis, design, testing and development of low-temperature cryogenic systems.
- Applied research and development of new technology concepts within materials and cryogenic system.
- Development of sequences and procedures to perform cryogenic transfer operations
- Use the engineering standards to support analysis and calculations
- Gain knowledge on computer aid design tools (CAD): Thermal Desktop, NX Space System Thermal, ANSYS/FLUENT, SpaceClaim.
- Learned how to use current cryogenic apparatus for the testing of cryogenic materials and systems.

Challenges

- Development of proposals for new ideas that required interdisciplinary concepts being applied into cryogenic and energy systems
- Self learning of data acquisition systems; fittings, piping and safety devices; electronics; and cryocooler concept and operations to assembly, operate and understand a cryocooler system.
- Learn how to resolve differences on engineering analysis between engineers in order to complete assigned tasks and satisfy safety and schedule requirements for projects.

Lessons Learned

- The great value of team work to complete tasks or projects
- Keep an open mind to different ideas for projects
- Acquire experience in different branches for diversity of projects and/or topics of interest
- Do not be afraid to ask as many questions as you can
- The voice of the experience from mentors and technicians in physical devices/systems can guide you to a realistic analytical solution
- Time management by means of schedule is important to organize task, know the time line of a project and maximize time spent on different work experiences.

Experiences

Acknowledgement

- NASA Pathways Programs
- All NE-F6 Branch Members
- Mentor: Jared Sass
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