Group 24: Magnetically Coupled Pump System for Cryogenic Propellant Tank Destratification

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<u>Needs Assessment</u>

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Table of Contents

Table of Figures

Table of Tables

Abstract

Effectively mixing cryogens without heat leak or rapid pressure rise is the project proposed by NASA Marshall Space Flight Center. The task at hand is to make use of the proposed technology of magnetic coupling that will mix the cryogens with the motor outside of the tank. In order to make the project successful, the team has been other than to design the tank and mixer system but to also fabricate the tank and to test it with water and liquid nitrogen.

1 Introduction

This project was proposed by NASA Marshall Space Flight Center in order to come up with a more effective way to mix cryogenic fluids, therefore keeping the temperature homogeneous throughout the tank. It was desired that an electric motor be magnetically coupled with a pump in order to reduce heat addition and pressure rise in the cryogenic tank. Currently the motor is directly coupled with the pump and operates in a submerged position within the tank. This is unsatisfactory as this process is costly and adds unwanted heat into the system.

For this project we will make use of magnetic coupling technology and devise a system that is capable of producing variable flow and limiting the pressure rise in the tank. This system must also be easily attached through a standard flange that is already in place on most tanks.

2 Project Definition

2.1 Background

Pressure control and destratification, or the process achieving temperature equalization by mixing the internal air to eliminate stratified layers, presents issues with long term storage of cryogenic propellants. Heat leak from the surrounding environment causes these propellants to boil causing the pressure in the tanks to rise and there is an increase in the fluid saturation temperature if the tank is sealed off. In order to reduce the environmental; heat leak in conditions such as ground/atmosphere and space/vacuum, foam and insulation are used. In order to decrease rapid increase in pressure, the propellants can be mixed to create a more uniform temperature condition within the vapor and fluid portion of the tank.

Currently and previously, the mixing process consists of using AC single and 3-phase motor systems which are directly coupled to a pump and placed within the tank itself or mounted to a flange with the motor operating in a submerged condition (Figure 1). Using this method heat will be generated within the tank causing the pressure to rapidly rise, the feedthroughs or connectors will create leak paths for potential failure, and it is expensive to develop such motors to operate in these low temperature conditions.

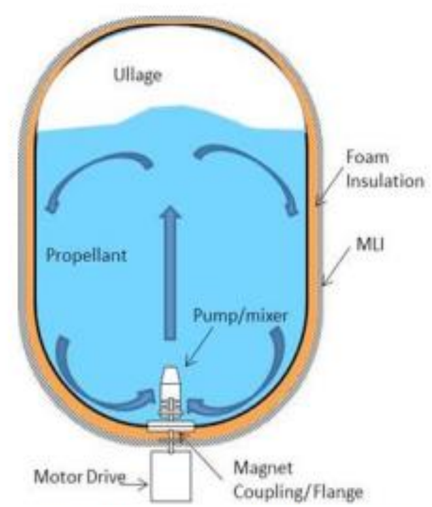

Figure 1: Current Tank Mixer System General Layout [1]

To decrease heat leak, high performance insulation systems are incorporated into the design of the tank, even with perfect vacuum,[2] thermal radiation can still contribute significantly to the total heat leak. The radiation from room temperature is also one of the main heat loads in cryogenic systems, and heat addition is what the team is trying to avoid throughout the entire project. Therefore the standard multi-layered insulation (Figure 2) used at the NASA Marshall Space Flight Center will be used throughout the project.

Magnetic coupling was introduced that may allow the placement of the motor outside the cryogenic tank. Magnetic couplings are generally used to transmit torque from one system to another where the magnetic transmission is required to maintain a hermetic seal to prevent leakage and contamination.[3] The magnetic coupling is used in this project to transmit rotational motion from the motor across the tank wall to a mixer/pump located

Figure 2: Layers of insulation currently in place on cryogenic tank

on the inside. The mixer/pump would be designed to operate in the cryogen receiving the magnetic rotational motion and imparting it to the fluid through impellers/etc. contained within a housing to produce flow up to 15gpm and pressure rise up to 5psid.

NASA has given us the task to design, fabricate, and test an electric motor-pump unit that makes use of magnetic coupling technology to position the motor outside of the cryogenic tank, while still providing sufficient pumping pressure/flow and incorporating insulation between the coupling and tank wall so as not to introduce additional heat leak.

2.2 Need Statement

NASA Marshall Space Flight Center is in need of a way to mix cryogenics without adding heat to the system. Currently a motor is placed inside the cryogenic tank in order to operate the mixing pump. The motor not only inserts heat to the system but also causes a rise in pressure. Additionally many of the motors used inside the system are costly and impractical. The purpose of this project is to reduce the heat added to the cryogenic system while effectively mixing the cryogenics to uniform temperature.

"Due to the motor used inside cryogenic tanks there is to much heat addition when mixing the fluids"

2.3 Goal Statement

"Design a better way of mixing cryogenic fluids"

- Minimize heat addition to cryogenic system
- Reduce the pressure rise to less than 5psid
- Magnetically couple motor shaft to pump shaft
- Contain a minimum number of parts and be compact in arrangement

2.4 Constraints

- <u>Budget</u>: The overall budget of the project consists of $500 from the Space Florida for the purchasing of motor, magnets and fabrication costs. The materials will be provided by our sponsor as long as a prepared list is submitted prior to November. Therefore a complete list of materials will be needed prior to this date.
- <u>Ease of assembly:</u> The design must be able to be fitted to the standard 6" ConFlat flanges in order to be properly and easily installed into the current model of tanks.
- <u>Size:</u> The design must be compact and easily portable.
- <u>Materials and Magnets:</u> The materials used in the design must be able to withstand such low temperatures without any structural damage. The materials of the tank must also be non-magnetic in order for the coupling to be successful. There must be enough magnets used in the design to ensure that there is enough coupling strength to make any rotation motion one-to-one. The magnets chosen must also be able to penetrate through the tank material as well as the insulation used around the tank.

2.5 Design Requirements

Table 1: List of the Specified Design Requirements

Requirement	Specification
Tank Size	• Height: 3ft • Diameter: 18 in
Insulation	• 0.5 in of foam • >20 layers of multi-layer insulation (MLI)
Mounting	• Mounted to 6 in flange • Flange has 4 in port into tank
Pump Motor	• Variable Flow Rate : 3 – 15 gpm • Can generate no more than 5 psid rise in pressure
Additional Requirements	• Tank must be adiabatic to surroundings • Pump shaft must be magnetically coupled to the motor shaft • Friction must be held to a minimum • Tank material must withstand extremely cold temperatures between 63K – 77.2K

2.6 Methodology

The best methods to construct the magnetic coupled mixer/pump system require iterations, mathematical analysis, and much more for optimal design. These iterations consist of preparatory design methods to finalize the design selected. These preparatory design methods are taken from several fields of study in the engineering field. These actions emphasize the overall direction of constructing the magnetic couple mixer/pump system:

- Formulate a reasonable size of the system through theoretical estimation
- Determine the best cryogenic material and thermal fluid system design by researching the specific fields in engineering
- Choose a multi-layered insulation suitable for cryogenics
- Broaden research to obtain a suitable motor and impellor to create a appreciable fluid flow rate
- Establish a financial plan and spend based on the budget
- Utilize engineering computer software such as CAD Drawing
- Create Gantt charts, blueprints, virtual systems or theoretical calculations sheets. These theoretical calculations were derived from magnet lab testing.
- Search the market for useful materials/products with great quality and price.
- Present the details of the project to evaluators, sponsors, and the general public

- Finalize the decision and construct the project satisfying the objectives

Based on these actions, the system will be a successful sponsored project with the capabilities of being introduced to the market.

3 Conclusion

The expected results or this project is to design, fabricate and then an electric motor pump unit that makes use of magnetic coupling technology by the end of the spring 2015 semester. The tank for the water and liquid nitrogen will also need to be fabricated. The pump will be required to function in both water and liquid nitrogen, and be able to produce variable flow (from 3-15 gpm) and a pressure rise (up to 5 psid).

The next step would be to start 3D modeling the test tank and the pump design. The material to be used in the design will also need to be selected next as well as deciding what motor will be selected. A list of the materials and parts needed will be completed prior to November in order to get them from our liaison engineer at the NASA Marshall Space Flight Center.

4 References

[1] Senior Design Project Definition Group 24. N.p.: n.p., n.d. PDF.

[2] W., Van Sciver Steven. Helium Cryogenics. New York: Plenum, 1986. Print.

[3] "Magnetic Couplings | Technology | Magnomatics." Magnetic Couplings | Technology | Magnomatics. N.p., n.d. Web. 25 Sept. 2014.