Lunar Water Storage Facilities

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ABSTRACT

Problem Statement:
Design a feasible storage facility for water on the surface of the moon. The major considerations are the lunar environmental conditions and the ease of operation.

Design Constraints:
- Lunar Environment
  - Temperature Range 41 K to 400 K
  - 14 Day-Night cycle
  - Gravity is 16.6% of Earth's Gravity
  - Hard Vacuum
- Ease of Operation
  - Safety
  - Cost
  - Operability (meets design specs)
- Facility
  - Store 10 000 kg of water
  - Throughput of 24 hours
  - Automated

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INTRODUCTION

Transporting water to and from the Earth is a high cost and high-risk procedure, this causes the need to develop foundations for creating infrastructure on the Moon to transport and store water in a safe and economical manner. This capstone project takes on the objective of developing a conceptual design for a water storage facility that can operate on the surface of the Moon. The water storage facility must be able to store 10,000 kg of water, and then output this water as a liquid for hydrolysis. The Lunar water storage facility must be able to function automatically and operate safely and reliably in Lunar conditions.

METHODS AND MATERIALS

Initial Concept Design Analysis
- Each team member brainstormed an idea to solve the design problem.
- A decision-making matrix was created to rank each idea based on safety, operability, and cost
- The final design was selected by a ranking system considering the ease of operational criteria.

Thermal Analysis
- Detailed calculations to understand how the equipment reacts to the extreme Lunar temperatures.
- Simulations, like the one shown in Figures 4 and 6, were created to show the temperatures of each component for all operating conditions.

Energy Analysis
- Finding the required energy to keep the facility operating.

Mass Analysis
- Finding the total masses for each component.
- The mass is important as the cost directly correlates to the amount of mass for the entire facility.

Design Load Analysis
- Structural analysis for where pipe supports are required, and internal pressure analysis to determine minimum thicknesses.

Pipeflow Analysis
- Bernoulli equation analysis with major and minor loss coefficients for compressor and pump requirements

Material Requirements
- Relatively light weight.
- Expandable materials to accommodate freezing water.
- Withstand Lunar temperatures.

Materials to Highlight
- PTFE – transfer hose.
- Polycarbonate – storage vessel.
- Forged 316 Stainless Steel – most metallic components.

Design

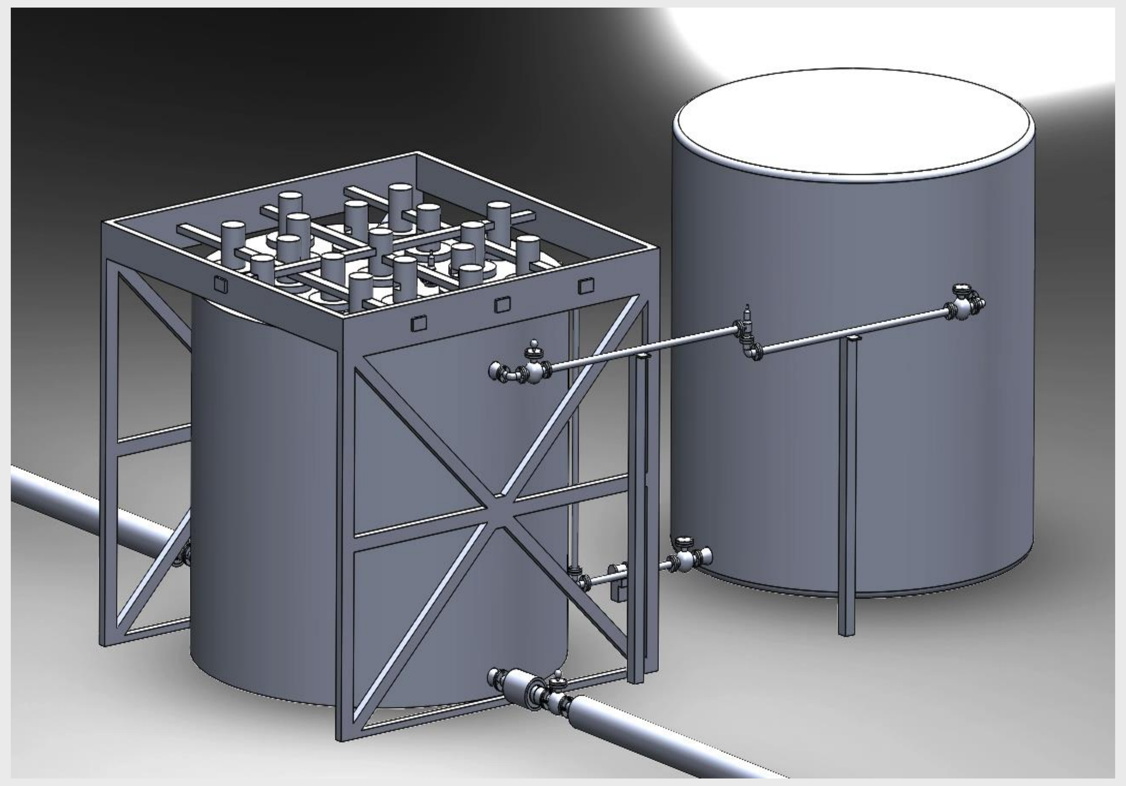

Figure 1. Overview of the Final Design for the Facility (Storage Vessel left, Nitrogen Tank right)

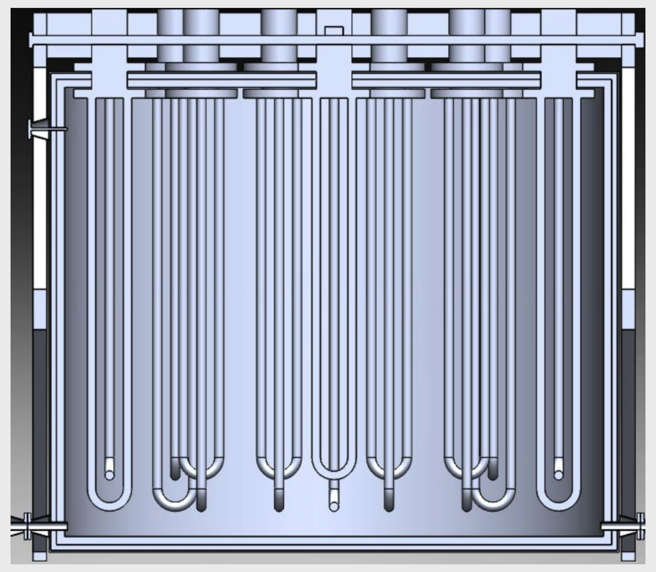

Figure 2. Cross Section Of Storage Vessel to Show heating Inserts

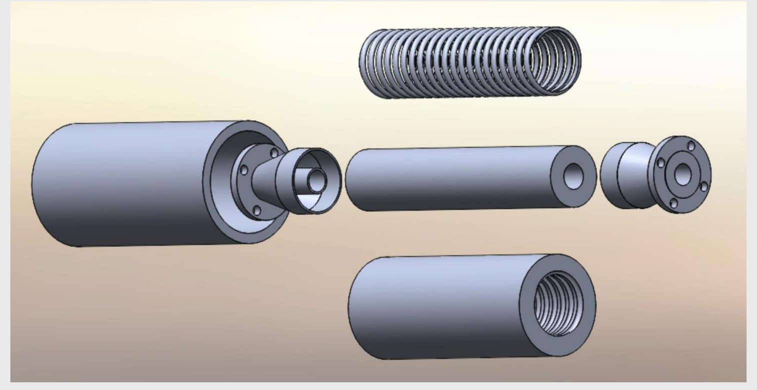

Figure 3. Inlet/Outlet Hose Design (See Heating Coil)

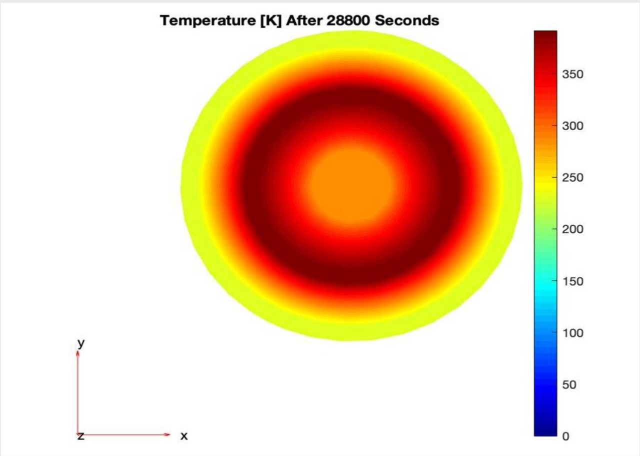

Figure 4. Thermal Analysis Simulation of Hose Assembly

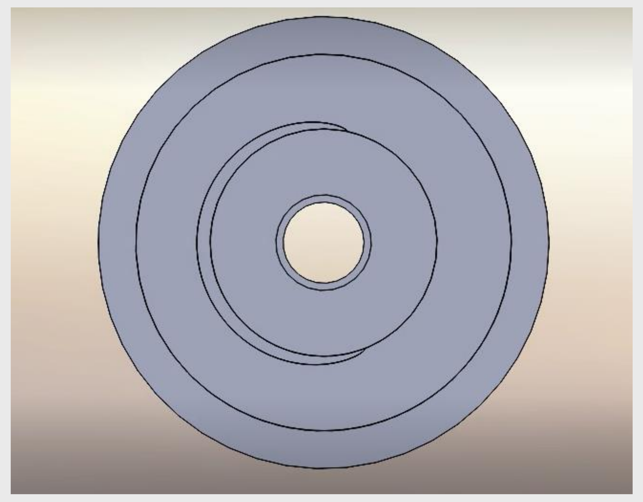

Figure 5. Cross-Section of Transfer Hose

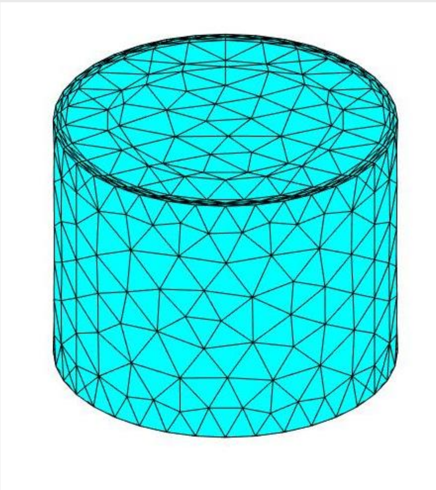

Figure 6. Thermal Simulation Mesh Object of Storage Vessel

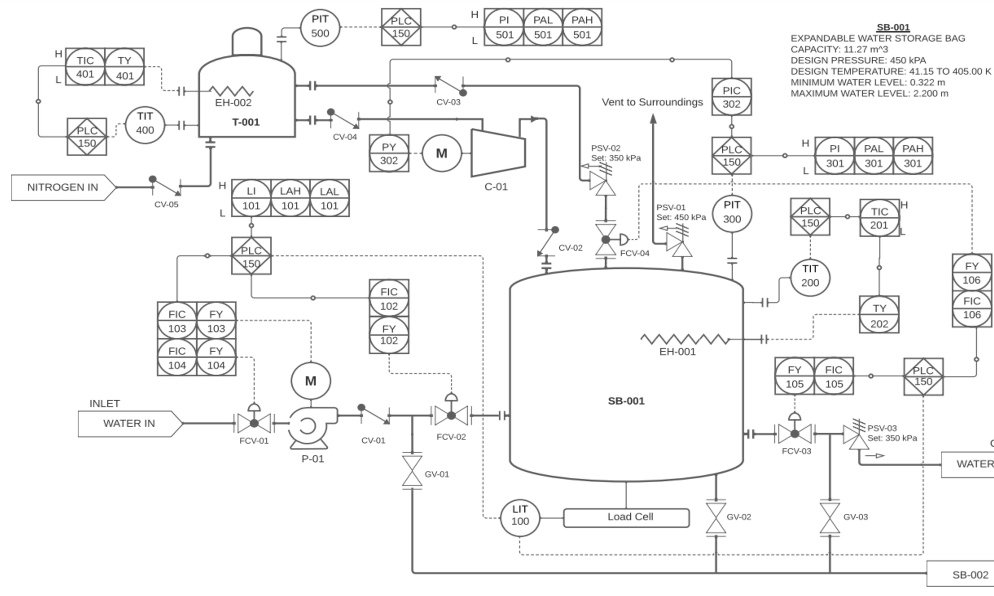

Figure 7. P&ID Showing PLC and Instrumentation to Implement Automation into the Process

DISCUSSION

Materials
- All materials analyzed perform as intended for the range of temperature extremes.

Throughput
- To achieve a throughput of 24 hours, the inlet transfer pump must have a flowrate above 1.41 m^3/hr.
- This minimum flowrate allows for the storage vessel to be emptied in 8 hours and filled back up in another 8 hours; stored ice can be melted in 8 hours if required, creating a throughput of 16-24 hours.

Facility
- The storage vessel has a volume of 11.275 m, which can hold 11,274 kg of water (at 283.15 K).
- Heating system in place to overcome freezing temperatures on the moon (refer to Figure 2 and Figure 3.
- Inlet and outlet water transfer lines (shown in Figure 3) are redesigned PTFE hose to replace heavy piping.
- The storage vessel shown in Figure 1, is a redesigned polycarbonate flexible water container to replace heavy pressure vessels.
- The storage vessel and hose design in Figures 1 and 2 can expand elastically with the expansion of water as it freezes.

Operation
- Optimum operating conditions are met by adding nitrogen gas to the storage vessel.
- This allows for controlling the pressure inside the vessel to maintain water at its intended phase.
- This also allows the optimum temperature range to stay within the material specifications.
- Operating Pressure is 350 kPa and Operating Temperature is 283.15 K.

CONCLUSIONS

Water is an essential resource to further progress space exploration as it is critical for life support and rocket fuel. The purpose of this project is to develop an economical and feasible design to store water directly on the Moon. Although storing and providing a consistent water source on the Moon offers tremendous benefit for exploration, the challenges ahead are limitless.

REFERENCES

[1] Etherington, D. (2020, August 31). *First commercial earth-to-moon communication relay satellite planned for 2023*. TechCrunch. Retrieved April 3, 2022, from https://techcrunch.com/2020/06/16/first-commercial-earth-to-moon-communication-relay-satellite-planned-for-2023/