Lunar Water Storage

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Problem Statement

By the end of the academic year, Team 8 will design a system for Lunar Water Supply to store 10,000 kg of water on the Moon to be used for hydrolysis, with the ability to regulate its phase, which requires maintenance no more than twice per year.

Lunar Conditions

1. The atmosphere on the Moon is vacuum-like (2.96e-15 atm) [1].
   ➔ System requires pressure control.
2. There are extreme temperature fluctuations between the day and night-cycle.
   ➔ System requires temperature control, including root house and heaters, for water phase control.
3. Moon dust is highly abrasive.
   ➔ System must be protected or durable enough to limit maintenance requirements.
4. Lunar excursions are irregular and expensive.
   ➔ Maintenance planning must account for irregularity and long wait times.

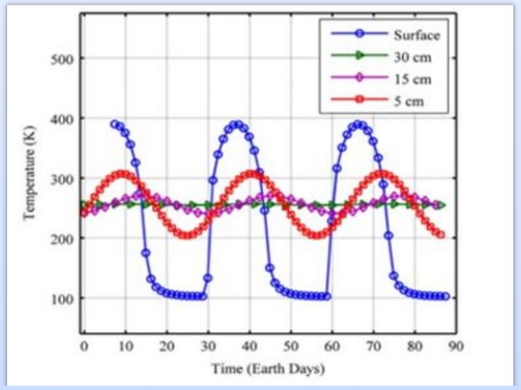

Figure 1: Temperature Variation as a Function of Depth on the Lunar Surface. Reproduced from [1].

Figure 2: Examples of a Root House. Reproduced from [2].

Stress Analysis

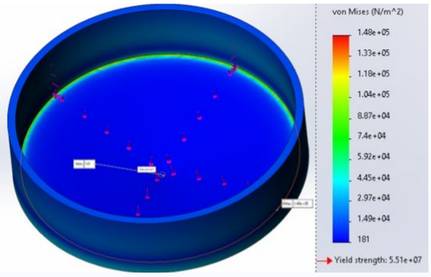

Figure 3: Stress Analysis of Primary Tank.

- Yield Strength of Tanks: 5.51e+07 [Pa]
- Max Stress Experienced:
  - **Primary Tank:** 5.59e+04 [Pa]
  - **Secondary Tank:** 4.85e+04 [Pa]

Power Requirements

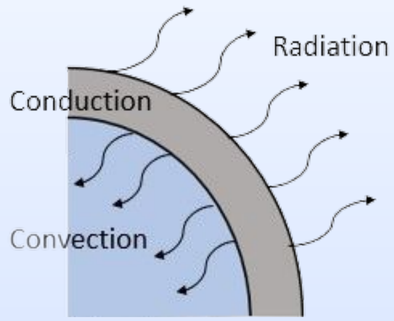

Figure 4: Modes of Heat Transfer Through the Tanks.

Primary Tank:

- Power Required: 10,476.9 [W]
- Temperature of Heating Elements: 290.2 [K]
- Heat Loss: 222.19 [W]

Secondary Tank:

- Power Required: 2,967.51 [W]
- Temperature of Heating Elements: 286.3 [K]
- Heat Loss: 109.39 [W]

Pressurization Requirements

Oxygen will be used to maintain atmospheric pressure in the tanks.

Considerations:

1. Delivery launch delays from Earth.
2. Leakage and dissipation of oxygen in the tanks.
3. Regular deliveries occurring only once every six months.

Oxygen required for a 6-month period: 31,809 [mol]

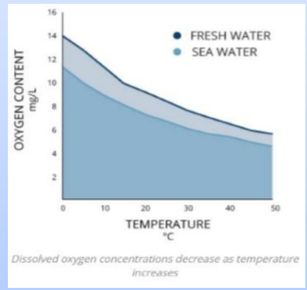

Figure 5: Oxygen Adsorption of Water. Reproduced from [3].

Materials

- **Aluminum 6061** makes up the structure for the primary and secondary tanks, as well as the piping connection.
- **Aerogel insulation** (used by NASA) layers line both tanks. Thermal conductivity of 0.004 W/mK.
- Heating elements are U-shaped coils, primarily comprised of nichrome and copper.

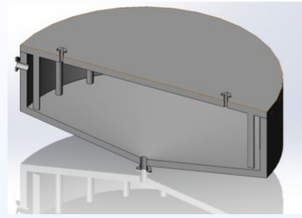

Figure 6: Internal View of the Primary Tank (left), Material Layering of the Tank Walls (top right), & the Internal U-Shaped Heating Coil (bottom right). Reproduced from [4].

Final Design

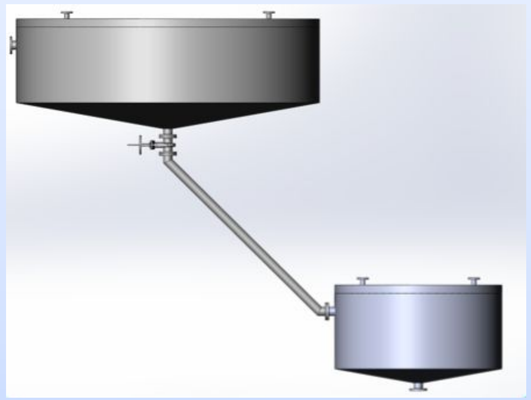

Figure 7: Assembled View of the Two-Tank, Two-Phase Water Storage Solution.

References

[1] LUNAR RECONNAISSANCE ORBITER: Temperature Variation on the Moon North Pole Maximum Temperature Minimum Temperature. (n.d.). www.nasa.gov

[2] "Project Update: A large, low-energy root cellar - Endeavour Centre." https://endeavourcentre.org/a-large-low-energy-root-cellar/ (accessed Mar. 21, 2023).

[3] "Dissolved Oxygen," Fondriest Environmental, Inc, Nov. 19, 2013. https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolvedoxygen/ (accessed Dec. 05, 2022).

[4] "4U tubular heater element , four U-shape water heating element 1500W - Coowor.com." https://eyou.coowor.com/shop/product-detail/20161019181301779 6.htm (accessed Mar. 21, 2023).