Lunar Facility Heat Exchanger

Active Thermal Management for Industrial Processes on The Moon

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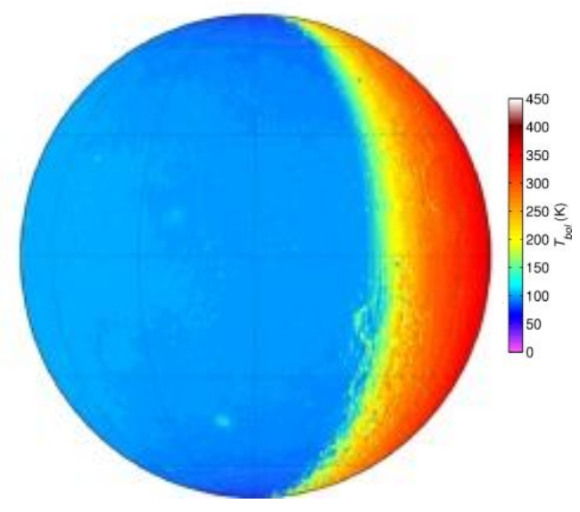
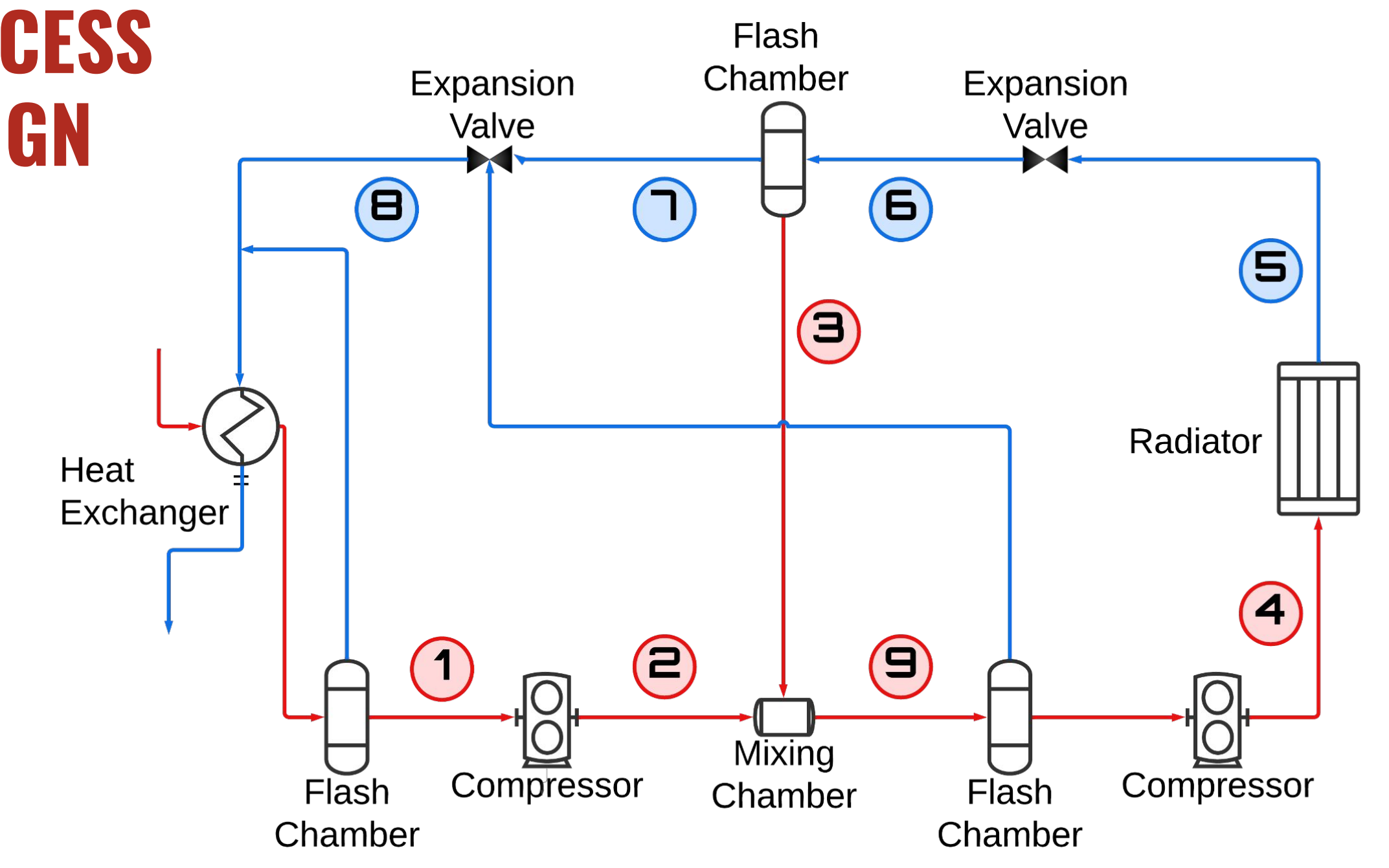
ABSTRACT AND INTRODUCTION

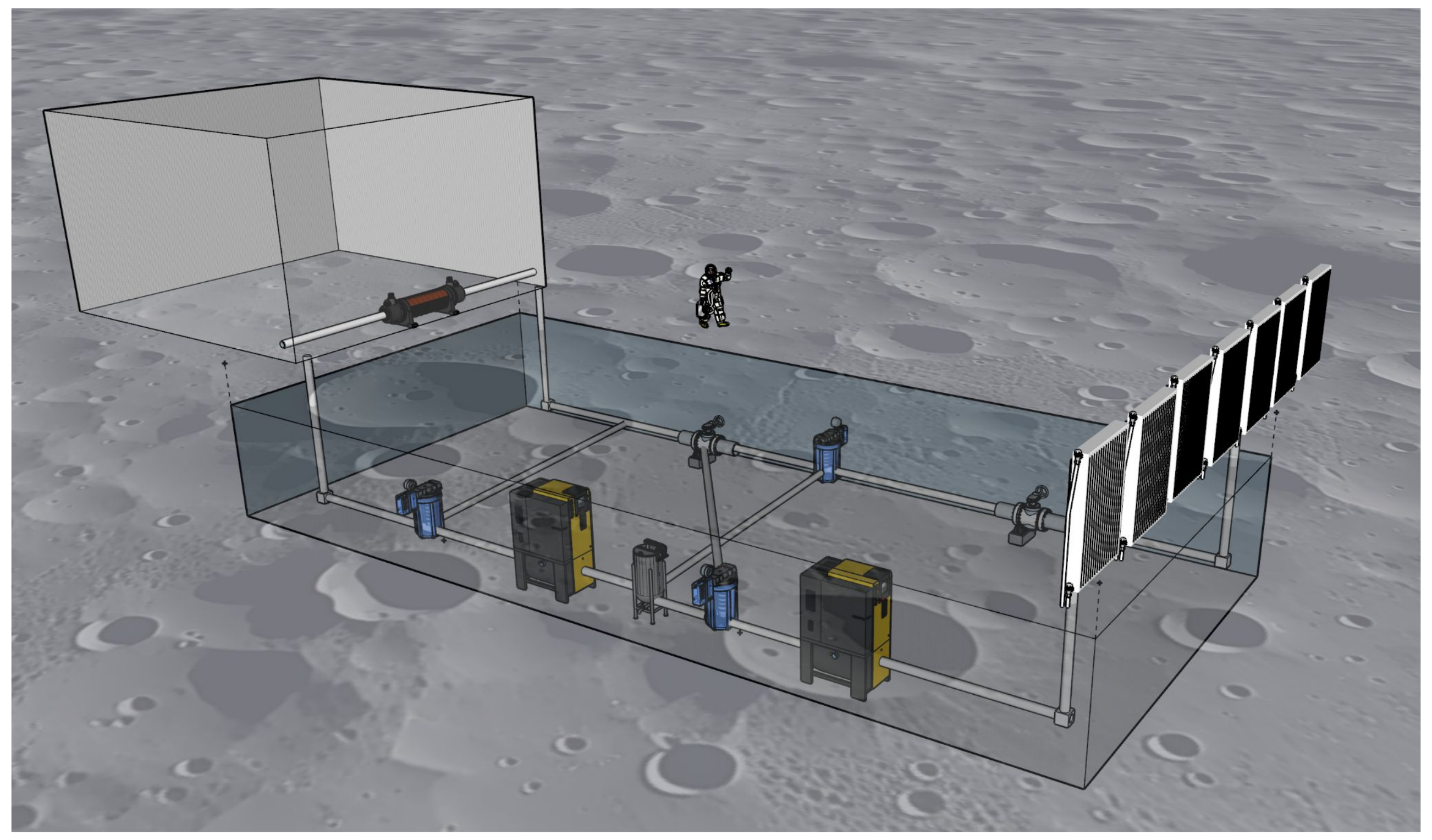


The design challenge is to investigate the technology and controls needed to dissipate heat generated from an industrial processes to a lunar environment. The key goal is to remove 50kW of waste heat from an arbitrary facility while maintaining temperature and pressure conditions of 25C and 1 atm.

Design Constraints	Boundary Conditions
○ Weight restriction: 1000kg ○ Power Budget: 10kW ○ Operation: autonomous for 6-month periods (bi-annual cleaning)	○ 14 day and night cycle ○ Vacuum of Space – no free convection for heat expulsion ○ Temperature Range of 50K to 450K

PROCESS DESIGN





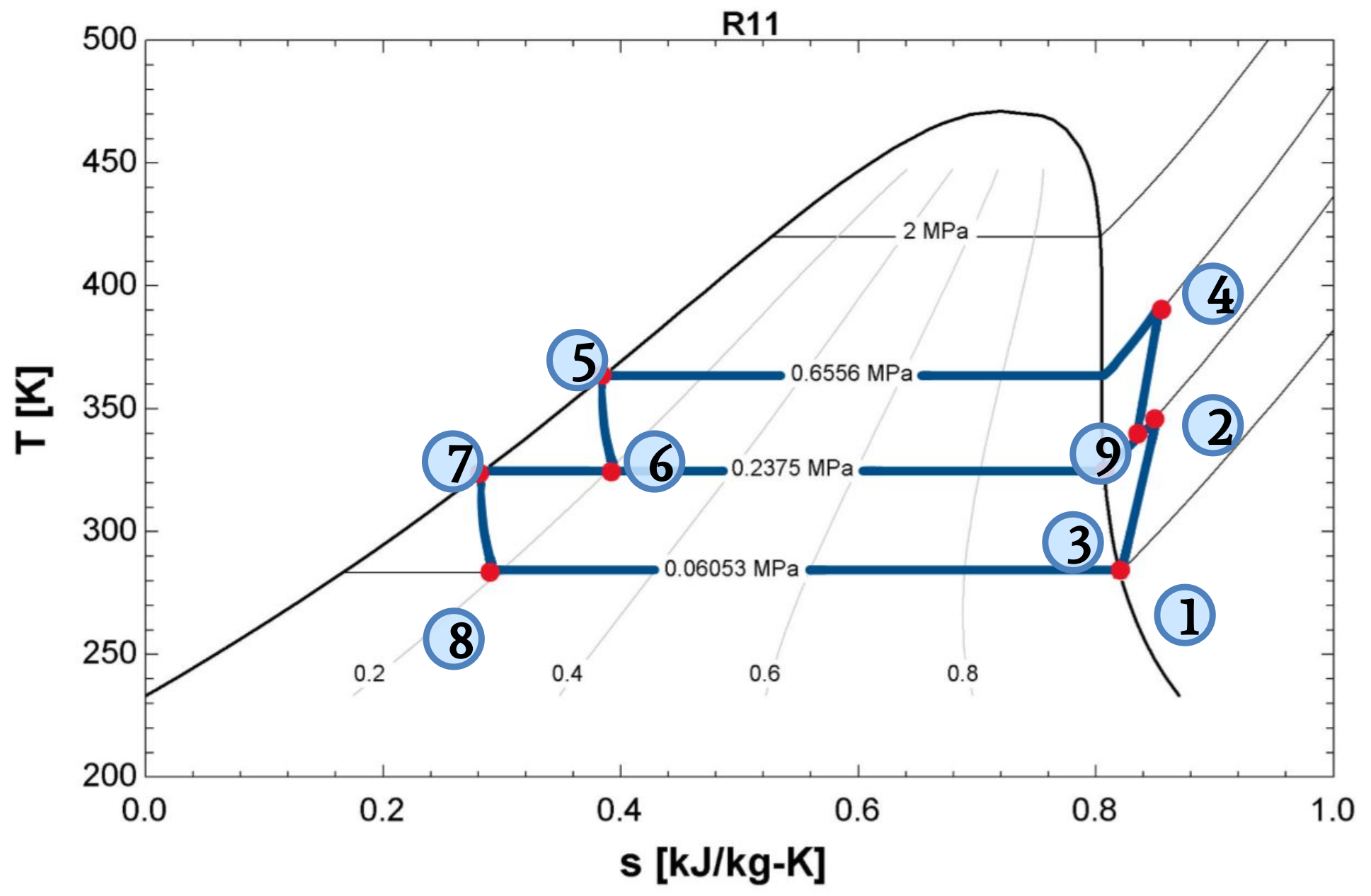
METHODS

Engineering Equation Solver (EES) and Solidworks: It has a larger database of information regarding fluids and is more efficient than performing traditional calculations ourselves.

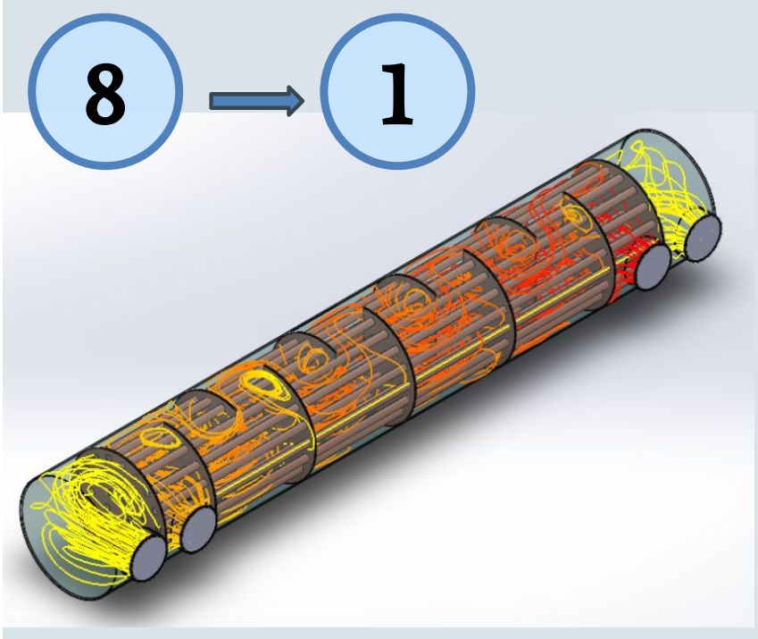
- Fluid criteria: corrosion to metals, triple point pressure, viscosity, conductivity, molar mass
- Calculations performed for optimization: heat pipe specifications, heat exchanger weight, multistage cycle
- Solidworks: used to run simulations for verification

Thermodynamics: Using our knowledge of thermodynamics, we compared single loop, cascading, and multistage cycles.

- A constant heat load and a wide variety of external conditions necessitates for an active heat transfer system.
- Multistage adds more components and weight, but lowers the overall power budget and provides a COP of greater than 1.



DISCUSSION

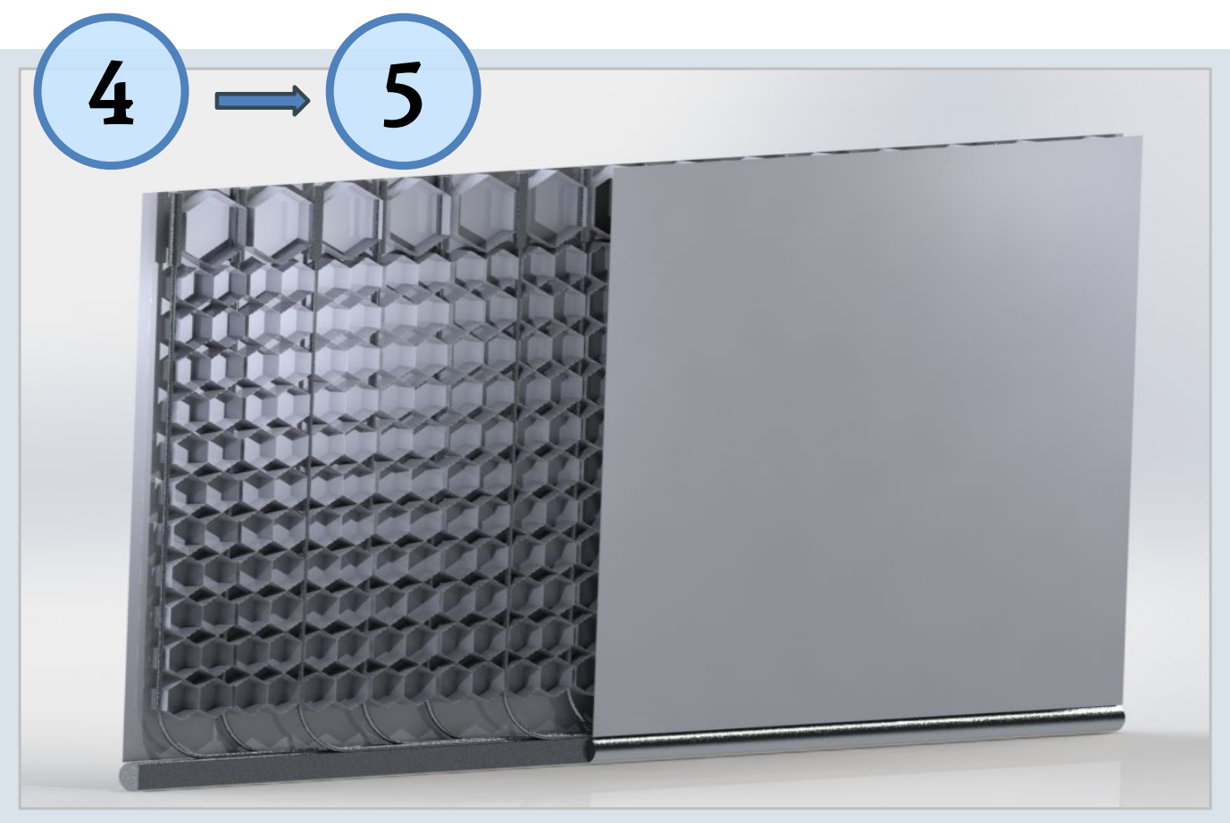


Facility heat exchanger:

- 50kW of waste heat is removed from the facility via a hot water loop
- Shell side contains hot water
- Tube side contains R11 refrigerant

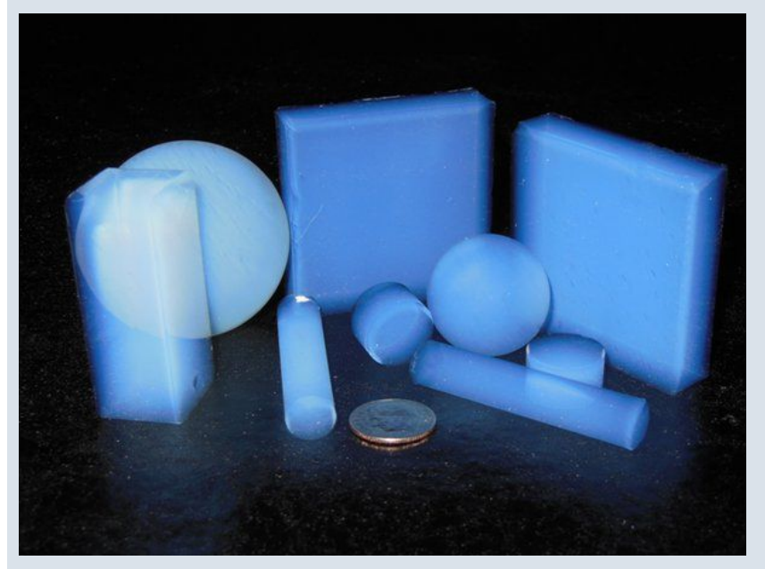
Radiators and Heat Pipes:

- Radiation is the only way to reject heat since there is not atmosphere on the moon
- Heat pipes rapidly transfer heat from the R11 to the ~400 m² of panels
- Weight is minimized by using thin hexagonal supports and optimizing the array of heat pipes



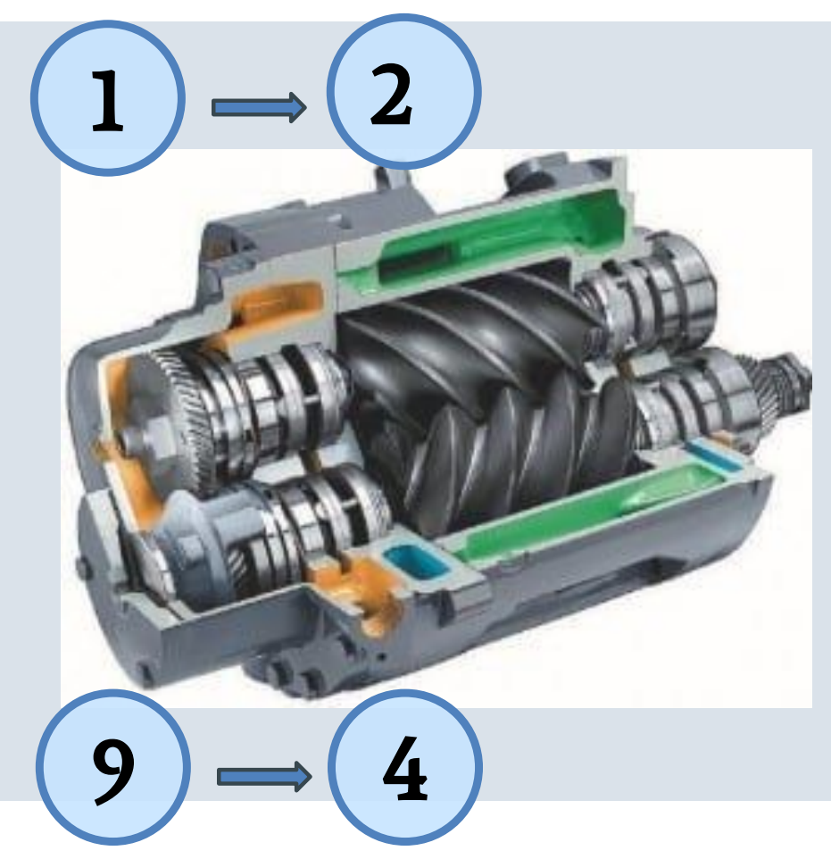
Heat Shielding:

- A shield is required to prevent our system from heating up due to the direct sunlight during day
- AZ-93 coating will be applied to the outside of the radiators to reflect away the radiation and prevent our heat pipes from becoming inefficient



Insulation:

- Lunar regolith is a suitable insulator for underground components
- Coated in Cr3C2-NiCr for abrasive protection
- Aerogel used for above ground components because air is lightweight and acts as a good insulator.



Compressors and Flash Chamber:

- The multistage cycle requires the use of two compressors and a flash chamber
- Oil free rotary compressors are required because of the moon's microgravity
- The flash chamber has been selected to have efficient separation for easier maintenance.

MATERIALS

- **Shell and tube heat exchanger**: 304 Stainless Steel with copper tubes inside
- **Pipes and valves**: 304 Stainless Steel is chosen to balance weight, strength, and durability
- **Heat Shield Coating**: AZ-93 White Thermal Control, Inorganic Paint minimizes the amount of solar radiation absorbed while still rejecting 89-93% of the heat
- **Radiator Assembly:** Aluminum 6061-T6 is commonly used for space application
- **Sensors**: Silicon Diode Sensors have high accuracy and can withstand extreme temperatures
- **Working Fluid:** R11 meets our pressure, temperature, and triple point requirements. It is also less toxic than other alternatives.
- **Heat Pipe Fluid**: Ammonia is commonly used in space application

RESULTS

- The shell and tube heat exchanger is 35.64kg, making it lighter than the alternative 142.5kg plate heat exchanger.
- This system requires 22kW of power at lunar noon; this exceeds the power budget in order to achieve a reasonable size and weight for the radiator panel.
- A simulation prototype was developed to demonstrate the interdependencies between each section of the system. This provides an example of a SCADA view of the system.

CONCLUSION

- Our design is able to remove 50 kW from a facility and maintain a temperature of 25C and pressures of 1atm. It will weigh about 12475 kg and has a maximum power requirement of 22kW.
- Our final design is a multistage cycle with R11 as the operating fluid. A shell and tube heat exchanger operates inside the facility, and a heat pipe radiator rejects heat into the vacuum of space via radiation.
- **Next Steps:** For future improvements, we would recommend looking into optimizing the shell and tube heat exchanger and consider axial grooved wick structures to improve heat pipe efficiency.

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