Camera Housing for Space Environments

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Background

Thermal cycling is a critical component of spacecraft qualification testing, but current thermal chamber environments limit real-time visual monitoring due to frost formation and hardware failure at extreme temperatures. Project VANTAGE addresses this challenge by developing a thermally regulated camera housing capable of protecting commercial imaging hardware while providing continuous live-stream video of deployable space structures during testing.

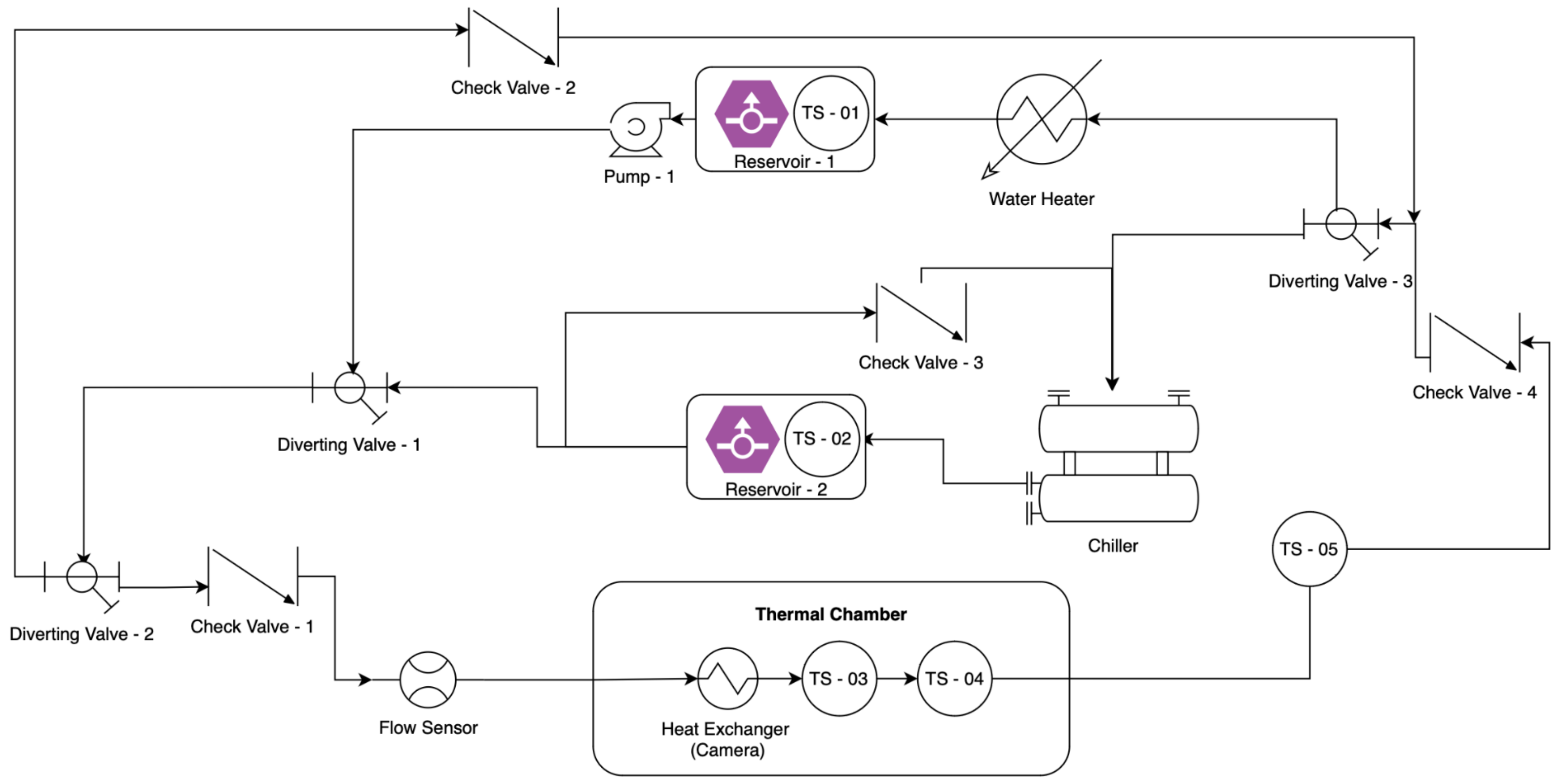

Figure 1. Plumbing Schematic

Hardware Integration

The VANTAGE system integrates a closed-loop heating and cooling network, thermocouples, flow and level sensors, motorized diverting valves, and an Arduino-based control architecture to maintain safe camera operating temperatures during chamber cycling. Active thermal regulation is achieved by pumping temperature-controlled water through a copper coil heat exchanger wrapped around the camera housing, while integrated safety systems monitor flow rate, coolant temperature, and emergency shutdown conditions in real time.

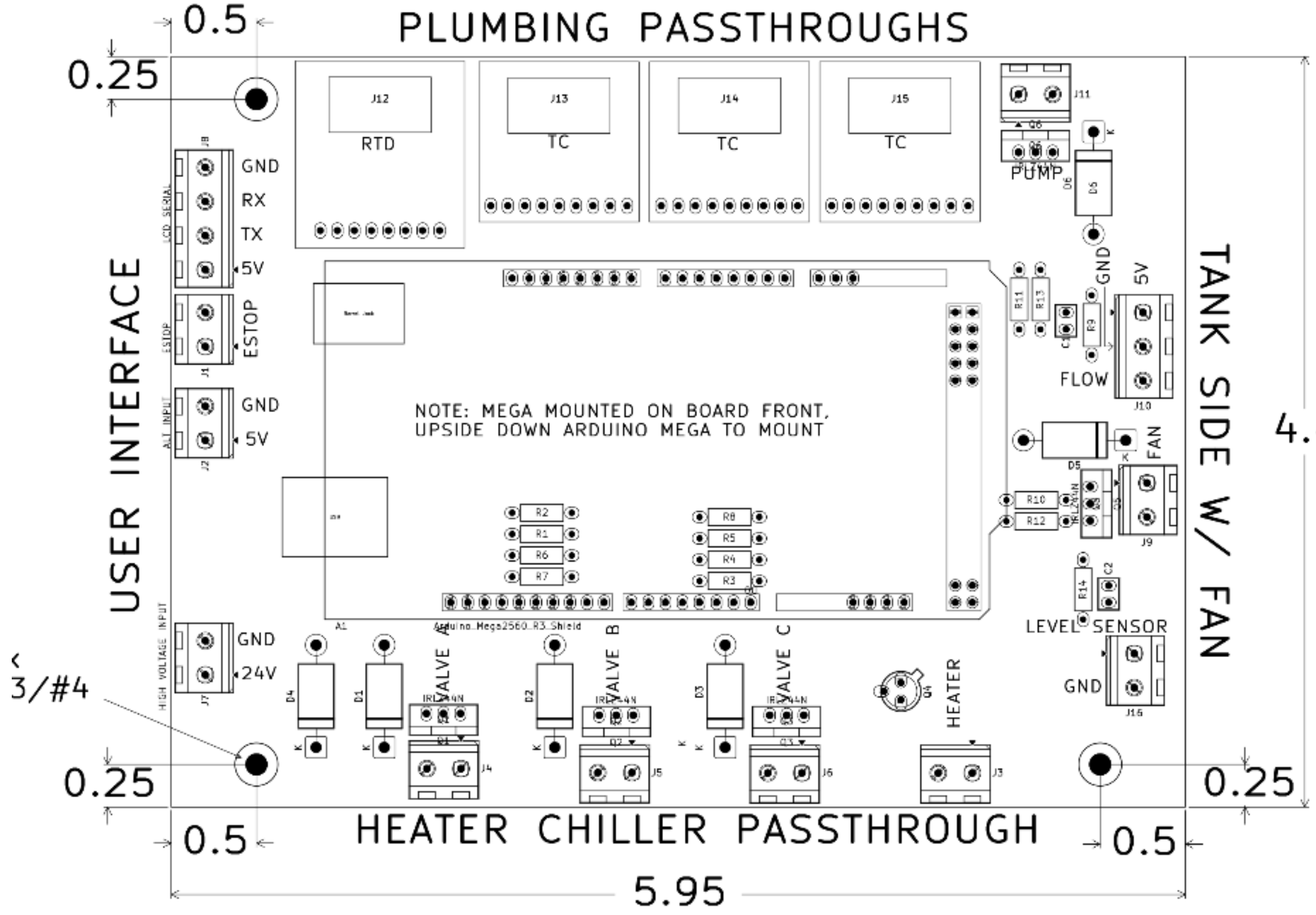

Figure 2. PCB Design

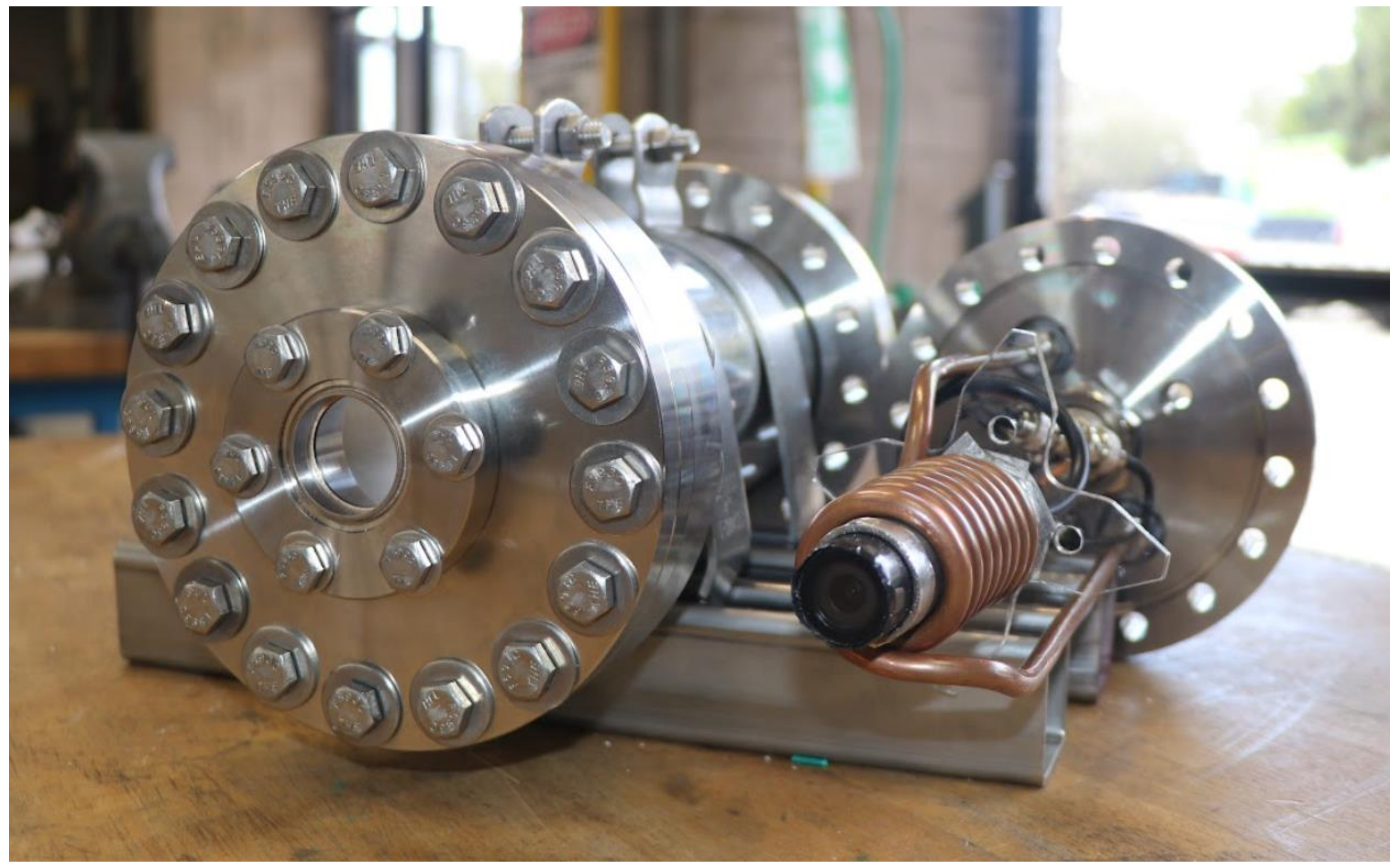

Figure 3. Camera Housing

Mechanical Design

The mechanical assembly consists of a stainless-steel vacuum housing with hermetic electrical and fluid feedthroughs, mounted on a rigid strut-channel base for portability and structural support. A sapphire viewport provides optical clarity and thermal shock resistance, while a graphite-wrapped lipstick camera is suspended within a thin-walled steel tube to minimize conductive heat transfer. The evacuated annulus and compact internal geometry enable reliable operation in extreme cryogenic and high-temperature environments.

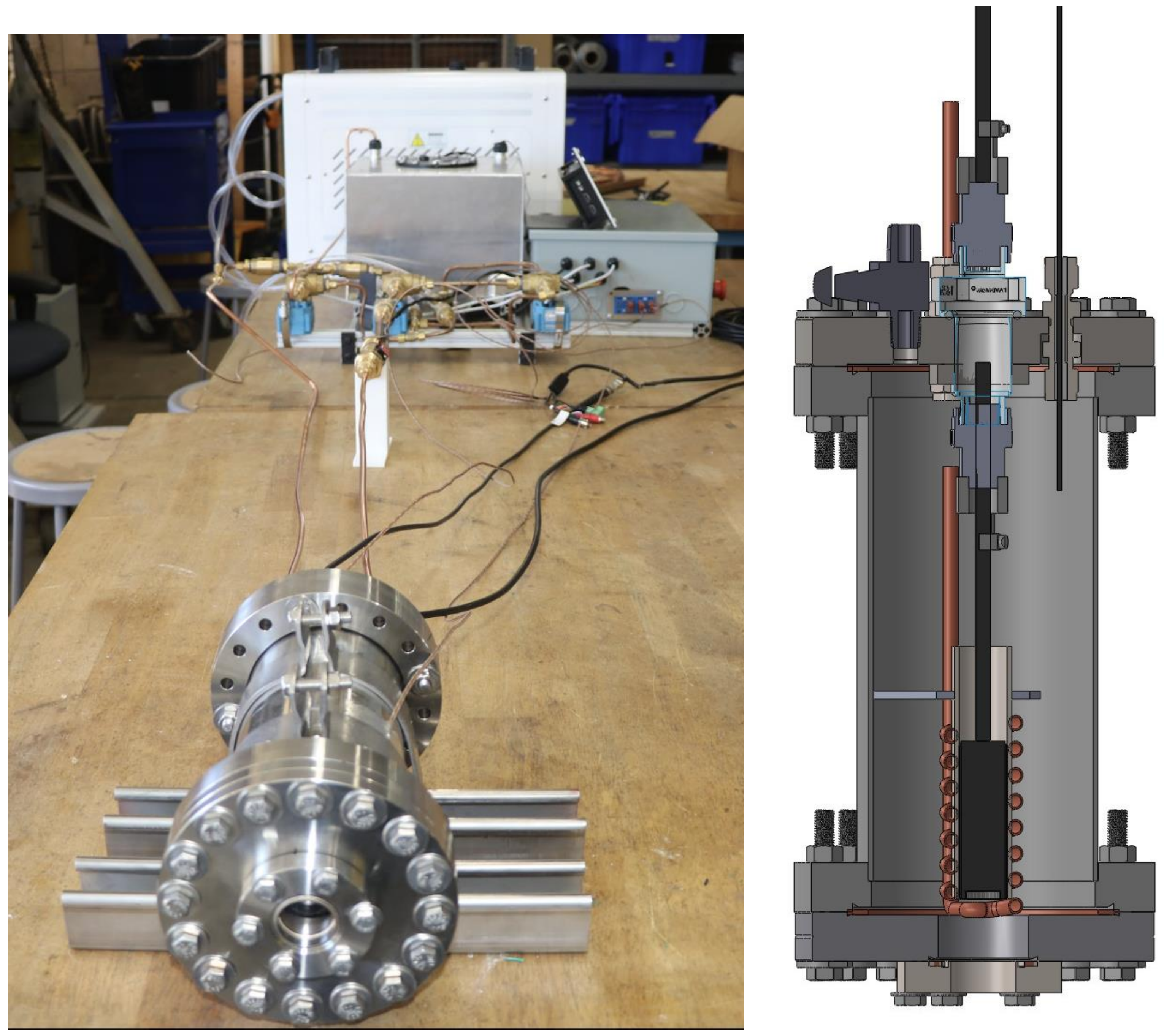

Figure 4. a) Full System View b) Housing Cross Section

Critical Testing

After electrical verification, the system underwent vacuum leak testing and ethanol-based seal validation. The housing was then fully submerged in a liquid nitrogen dewar measured at -160 °C for 30 minutes while operating with a 70 °C hot-water loop. Throughout testing, camera temperatures remained within the specified operating range, demonstrating effective thermal protection under cryogenic conditions. Corresponding camera temperature data is shown below.

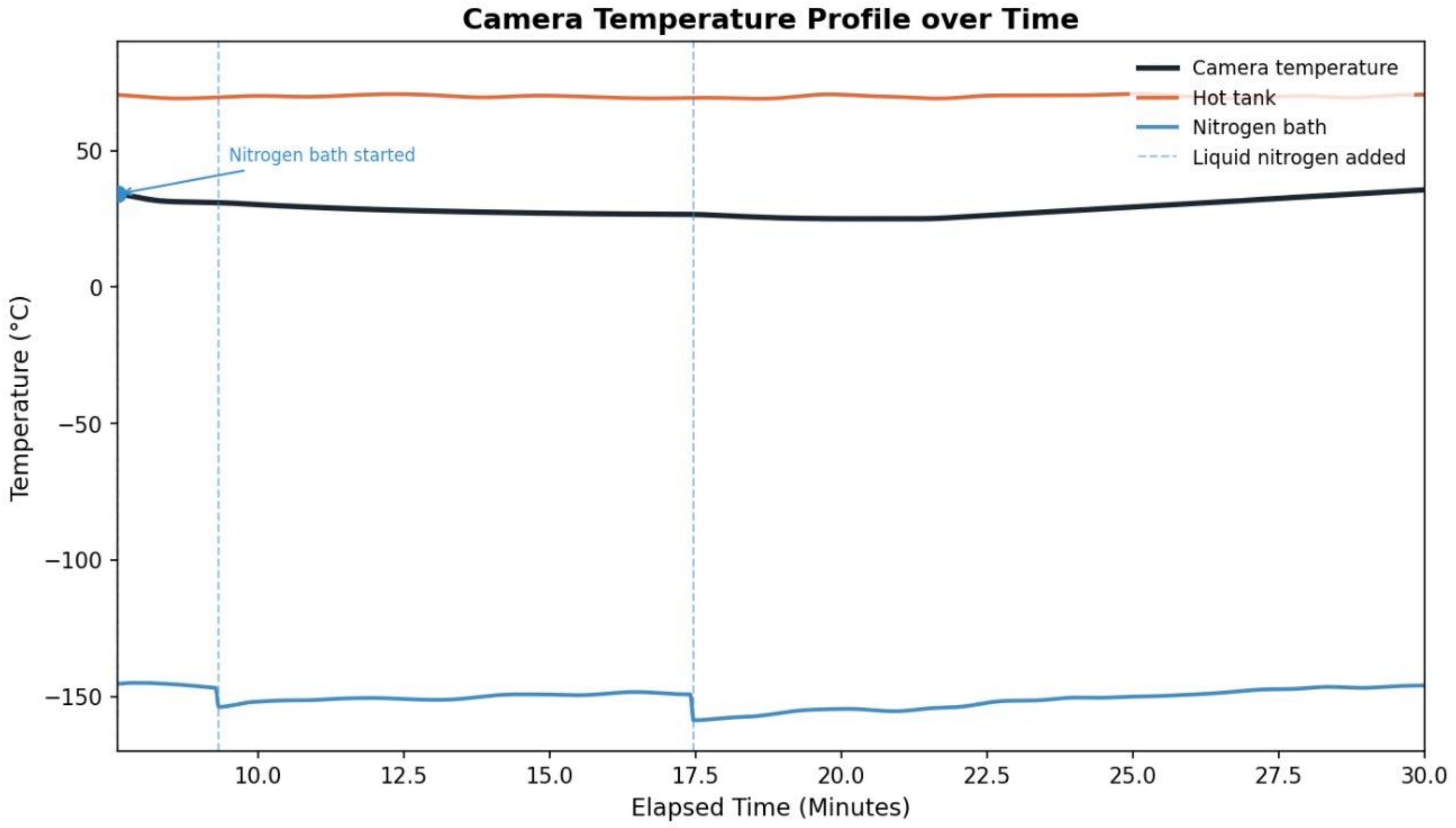

Figure 5. Cryogenic Test Results Measured from T-Type Thermocouple

Conclusion

Cryogenic testing validated the selected low-temperature-rated components and demonstrated successful thermal protection of the camera system. Post-test inspection revealed no moisture on the camera lens, confirming maintenance of optical clarity throughout operation. Future improvements include enhanced sealing components to further reduce leak rates and internal humidity, as well as the integration of a pan-and-tilt mechanism and a more advanced user interface with expanded temperature and flow-rate control capabilities. Nevertheless, the system enables higher-resolution thermal chamber visualization than was previously possible.

Acknowledgments

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