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C2Po3C-03: Quantum computer cryogenic cooling system

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In 2023 Criotec Impianti Srl awarded the contract with PsiQuantum for the design, manufacturing and commissioning of the PsiQuantum cryogenic distribution system.

PsiQuantum is a quantum computing company located in Palo Alto, California, aiming at the construction of the world's first useful quantum computer. The idea behind their concept is that if you want a useful quantum computer, you need fault tolerance and error correction, and therefore ~1,000,000 physical qubits—to address commercially useful quantum computing applications. While all mainstream quantum computing efforts require cryogenic cooling, in PsiQuantum's approach, these cooling requirements are relaxed relative to other prevailing technologies. Differently from the superconducting qubit-based quantum computing approaches requesting for milli-Kelvin temperature and dilution refrigerators in order to operate, the PsiQuantum single-photon detectors operate at liquid helium temperatures. Thanks to this "high temperature" it is possible to use existing high-power cryogenic infrastructures that allow for progressive levels of scaling and could help shorten the time needed to develop a large-scale quantum computer [1].

To achieve this goal, PsiQuantum plans to build a cryogenic system connected to an existing cryoplant and Liquid nitrogen supply in California.

The cryogenic system was the scope of this contract and included the supply of a liquid helium valve box, liquid helium transfer lines, nitrogen and helium vent lines and a helium ambient heater to be installed at SLAC National Accelerator Laboratory in California.

The cold valve box, equipped with 12 cryogenic valves DN10 for liquid helium, controls and delivers the liquid nitrogen and supercritical helium to the PsiQ cryostats used to test the PsiQuantum cryogenic quantum modules. The valve box configuration foresees the interface to one PsiQ cryostat with the possibility to upgrade in the future.

The valve box has been designed with an active copper thermal shield cooled down by the feeded liquid nitrogen, reducing the heat loads on the helium pipes as much as possible. Criotec Impianti successfully performed the FAT on the valve box including pressure test, cold shock tests and cold and room temperature leak tests.

The supply of the liquid helium and nitrogen is provided by about 70 meters of vacuum insulated cryogenic line with two headers (one for each fluid) within the same vacuum jacket. The lines is connected to the valve box on one end and to a connection box receiving the helium and the nitrogen from the SLAC infrastructure. The copper thermal shield, used to reduce the heat loads on the helium pipe, is cooled down by the liquid nitrogen pipe.

The vent lines are connected outside the building to a set of helium ambient. The heater has been sized to operate continuously without any active fan or heater to facilitate the warmup of the helium flow and introducing a pressure drop lower than 5 mbar at rated conditions.

All the components provided has been designed according to ASME standard and to the California's and SLAC's seismic specifications for buildings.

References

[1] <https://www.psiquantum.com/news-import/psiquantum-partners-with-us-department-of-energys-slac-national-accelerator-laboratory-to-access-state-of-the-art-high-powered-cryogenic-cooling-capabilities-for-large-scale-quantum-computing>

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