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Design and Benchmarking of the Underground Argon Cryogenics System for DarkSide-20k

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DarkSide-20k (DS-20k) is a direct detection dark matter experiment and currently under construction at LNGS. It involves a total of ~100 t of low radioactivity argon from an underground source (UAr) in its inner detector, half of which serves as target in a dual-phase (liquid/gas) time projection chamber (TPC).
The cryogenics system for the UAr must provide the cooling necessary to fill the TPC at a defined pace by condensing gaseous UAr, and must maintain stable thermodynamic conditions over the course of the experiment's lifetime of >10 years, necessary for the science search. Furthermore, the UAr has to be efficiently and continuously purified from impurities and radon for optimal signal yield and background mitigation.
We have designed and constructed a highly efficient and powerful cryogenics system, capable of turning over the UAr inventory within ~40 days with a recirculation rate of 1000 slpm in a gas purification loop. At its core is a condenser using liquid nitrogen and a downstream heat exchanger cascade which provides a maximum combined cooling power of 8 kW.
We present the design of the cryogenics system in view of the requirements for DS-20k. We further detail on the results obtained during a testing campaign of the system's integral components with a dedicated benchmarking platform at CERN and LNGS.
We conclude with an outline of the impact of our findings on the finalisation process of the design and provide an outlook to its integration at LNGS.

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