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C3Or3A-04: INFN DarkSide-20k AAr cryogenic purification system

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In 2023 Criotec Impianti Srl was awarded the CERN contract covering the design, manufacturing, and installation of the cryogenic system for the Neutrino Platform Dark Side-20k proximity cryogenics.

The DarkSide-20k experiment consists of an inner detector housed within a sealed stainless steel vessel and an outer muon veto, deployed within a ProtoDUNE-style membrane cryostat. It is currently under construction in Hall-C of the Gran Sasso National Laboratory, the world largest underground laboratory for neutrino and astroparticle physics, located in Italy. It is designed to either detect eventual Weak Interacting Massive Particle (WIMP) dark matter or to exclude a large fraction of the favored WIMP parameter space.

The scope of the CERN contract included the design, manufacturing and installation of:

- eight cryogenic valve boxes
- one warm valve box
- sixteen cryogenic vacuum super-insulated transfer lines distributing liquid and gas argon and liquid and gas nitrogen between cryogenic storage vessels, the valve boxes, and the 600-Ton liquid argon cryostat, for a total length of more than 200 m.

Each cold valve box, vacuum insulated and equipped with cryogenic valves between DN10 and DN65, performs a specific function within the proximity cryogenic system.

As the liquid argon used in the detection process needs to have a purity level in parts per million (ppm) oxygen equivalent and shall be cleaned from radon, the required detector sensitivity entails stringent purity requirements for the liquid argon, at the levels of less than 0.1 ppm for oxygen and less than 1 ppm for water and nitrogen. For this purpose, the cold and warm argon gas, as well as the liquid argon are purified by means of several purifiers equipped with a molecular sieve to trap water, a copper-coated alumina to trap oxygen, and an activated charcoal filter to trap radon particles.

The cryostat boil-off argon is recondensed in the gas argon condenser box by vaporization of the liquid nitrogen.

A liquid nitrogen phase separator is used to ensure a saturated liquid nitrogen phase to the argon condenser, while a liquid argon phase separator is used to ensure a saturated liquid argon phase returning to the cryostat.

The circulation of liquid argon from the condenser and from the cryostat through the filtering systems is guaranteed through two liquid argon pump valve boxes, each of them equipped with a liquid argon circulation pump.

All the valve boxes, having a diameter in the range 900-1700 mm and a weight between 400 and 1300 kg, are installed on a 4-floors, 14 m high metal structure.

During the design phase, detailed FEM structural analysis have been performed to assess the mechanical performance of the cryogenic system under different load cases, including severe seismic conditions.

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