Development of Cryogenic Installations for Large Liquid Argon Neutrino Detectors

M Adamowski1, J Bremer2, M Geynisman1, S Hentschell1, D Montanari1, M Nessi2 and B Norris1

1 Fermi National Accelerator Laboratory, PO Box 500, Batavia, IL 60510 USA
2 CERN, CH-1211 Genève 23, Switzerland

Cryogenic System Modes (II)

Background

• caverns at the Sanford Underground Research Facility (SURF), South Dakota, USA. The facilities will be developed, constructed and installed by the Long Baseline Neutrino Facility (LBNF).

Pressurization and de-pressurization system will be operational, guaranteeing that the cryostat system will be maintained within its operation limits. Once the cryostat argon level is below the surface. Each of these caverns will be equipped with a 17,000 kg liquid argon cryostat containing the detectors. The systems needed for the basic functioning of the cryostat, will be electrically fed via an UPS, guaranteeing an autonomous operation time of at least two hours. This system includes the PLC warm purifier. The liquid then goes through a phase separator: the gas eventually created during the transfer and purification process, is separated from the liquid and sent to the liquid argon supplier. For the LBNF cryostats we have decided to use a different fill method. There is only gaseous argon transfer form the surface to underground. Liquid is generated onsite in the condenser and from there it is transferred into the cryostat. The full chain is the following: liquid argon is delivered above ground, vaporized, transferred as a gas to the underground condenser, will be purified in the liquid form and will be returned to the cryostat to continue the cool down process. The condenser shall isolate the argon on liquid nitrogen cooled surfaces. The present, and thus the temperature of the saturated nitrogen bath, will be regulated to a value, such that the liquid argon enters the cryostat at the correct temperature.

Cryostat cool down. The cool down will be performed by atomized liquid argon being distributed inside the cryostat volume to cool it down slowly and uniformly, following the cryostat manufacturer’s guidelines and the TPC requirements. Liquid argon will be injected into the cryostat and mixed with a high speed gas purge argon stream in statemixers. An additional argon gas stream will provide the circulation inside the cryostat volume. The pressure in the cryostat will be regulated to a value just above ambient pressure. The gaseous argon will be sent to the external condenser, will be purified in the liquid form and will be returned to the cryostat to continue the cool down process. The condenser shall isolate the argon on liquid nitrogen cooled surfaces. The present, and thus the temperature of the saturated nitrogen bath, will be regulated to a value, such that the liquid argon enters the cryostat at the correct temperature.

The temperature of the liquid nitrogen will however also be regulated such that the argon cannot be cooled below its triple point. If the pressure inside the cryostat increases beyond the condenser capacity, gaseous argon will be released through pressure releasing devices. During this phase, the minimum temperature difference between any two points in the cryostat shall remain below 50 K. If this value is exceeded, the process will be stopped and restarted again once the temperature difference has lowered to about 40 K. This procedure will be continued till the warmup point in the cryostat has reached a temperature of about 130 K, after which the filling can start. This used method has been effectively tested in the LBNF 35 ton prototype and will be used in the membrane cryostats as part of this prototyping effort.

Cryostat filling. The liquid argon is taken from an external storage tank and pulsed to the liquid phase through a cold purification system. This system is based on the same principle as the warm purifier. The liquid then goes through a phase separator: the gas eventually created during the transfer and the purification process, is separated from the liquid and sent to the condenser while the liquid is directly transferred to the cryostat. Because of the volume of the different cryostats, the external argon storage tank will have to be filled several times by the supplier. For the LBNF cryostats we have decided to use a different fill method. There is only gaseous argon transfer form the surface to underground. Liquid is generated onsite in the condenser and from there it is transferred into the cryostat. The full chain is the following: liquid argon is delivered above ground, vaporized, transferred as a gas to the underground condenser, re-condensed in the onsite condenser and transferred as a liquid into the cryostat.

Normal operations. Once the cryostat has been filled to its nominal level, the liquid argon flow from the storage tank will be stopped, the liquid argon pump is turned on and the circulation and purification of the argon begins. Liquid argon is sent from the bottom of the tank through the cold purification and back to the tank. This step is essential to meet the high level of purity (100% oxygen equivalent contaminations) required for the proper functioning of the detectors. At the same time the boil off gas is condensed, mixed with the stream of liquid argon from the cryostat and sent to the cold liquid argon purification system for continuous purification. There are several contributions to the boil off: the static heat load of the cryostat, the signal cooling, the heat dissipated by the electronics, the heat deposited by the liquid argon circulation pump, and the heat leak into the transfer lines. They all contribute to an increase of argon gas production, which leads in turn to an increase of the cryostat pressure. A regulation system maintains the cryostat system at a stable pressure, while also providing re-condensation and purification of the boil off gas. A control system is in place to protect the cryostat system against over pressure situations: if everything fails, it will ultimately vent argon gas in a controlled way in case of over pressure, while supplying a clean flow of gaseous argon to the cryostat in case of under pressure.

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