XeLiPS: The Xenon liquefaction, purification and storage system

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Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

Abstract

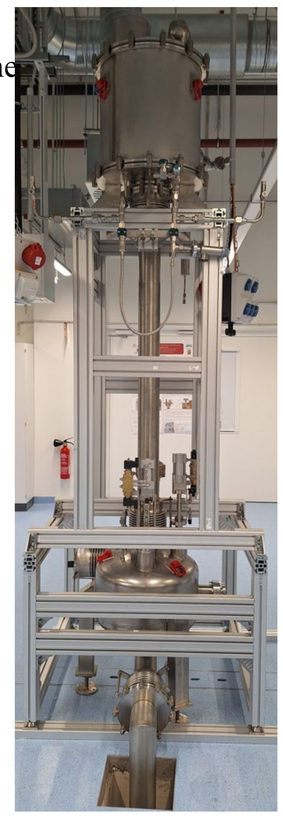
The Xenon liquefaction facility is designed to store, purify, and distribute up to 500 kg of liquid xenon to two neighboring laboratories. The liquid xenon can be recuperated by gravity in a cryogenic storage tank, which also serves as a pressure vessel to safely contain the gas at room temperature. Here, we describe the different parts of the facility and some new solutions for the design of the storage tank cooling system. The maximum flow in the purification system is about 20 l/min of xenon, corresponding to about 500 kg of purified xenon per day. The liquefaction of the xenon is done by a thermoacoustic pulse tube refrigerator (PTR) cryocooler (max power 120-140 W @T=160-180 K), supported by an auxiliary LN_2 cryocooler that can provide up to 170 W of additional cooling power, or can be used in place of the PTR in case of power failure. Xenon purification is performed in the gas phase, making use of a custom-built plate heat exchanger, reducing up the 90 % of the required cooling power of about 600 W in total. The remaining 10 % of cooling power (60 W) is provided by the cryocooler. A fast recovery system provides safe operation and can freeze xenon in the central cryostat with a cooling power of 500 W.

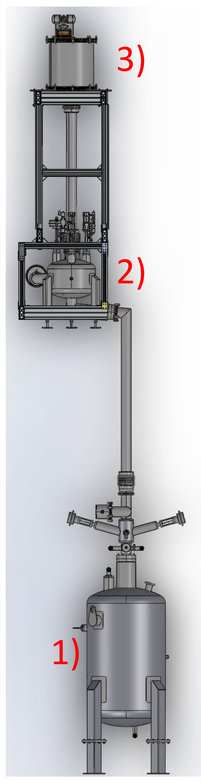
Introduction

The main goal of the new **XeLiPS** facility is to speed up the process of **filling** and **emptying** the liquid Xenon in the experimental chamber while providing a safe recovery option at all times. In addition, the facility can **continuously purify** the Xenon, also when the experimental chamber is not connected to the system.
The cryogenic facility consists of the following 5 subsystems:

- **Storage tank** (1) (up to 500 kg of Xenon at room temperature);
- **Valve Box** (2);
- **Cold Box** (3) with two cold heads (PTR and LN_2);
- **Purification Plant** (max Xenon flow up to 20 slpm);
- **Liquid Nitrogen Distribution** plant;

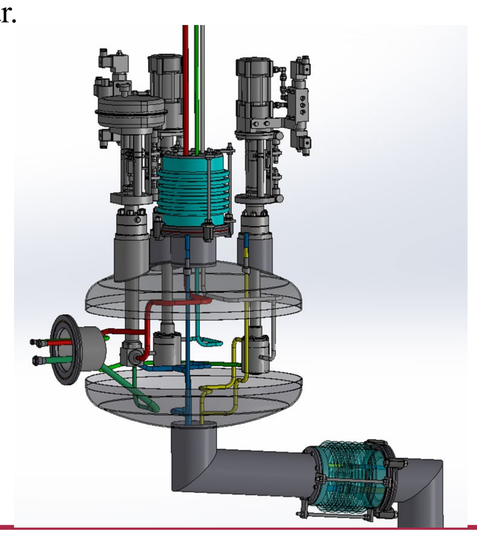
The liquid nitrogen is provided by the buffer reservoir of the building with a pressure of 2.5 bar and two dedicated cryogenic pipes are used for the LN_2 inlet and the outlet GN_2.

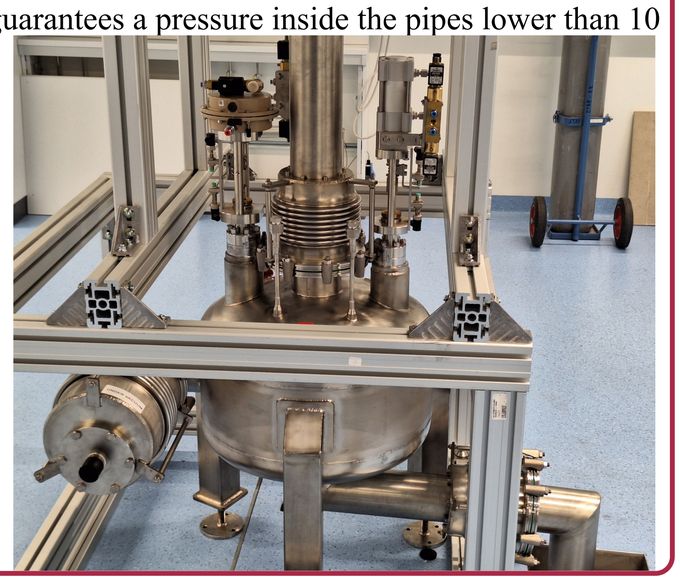




Valve Box

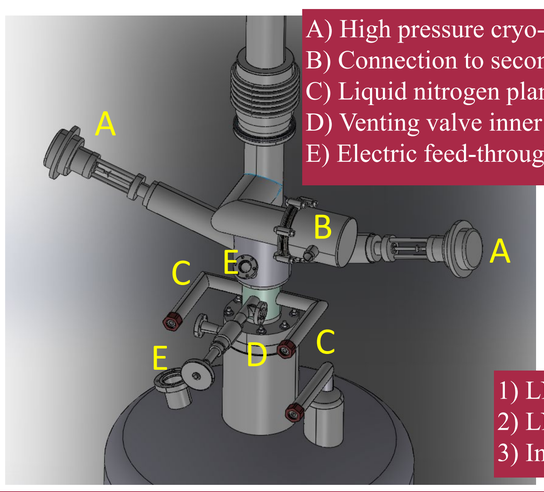
- The valve box can switch the flow of the L/G xenon from the storage tank or from the experimental chamber to the Cold Box, thanks to the three valves mounted in it.
- The valves are actuated by a pneumatic system through a Programmable Logic Controller (PLC) and the limit switches can verify the position of each valve.
- In case of a power failure, the pneumatic system can still be controlled manually.
- A set of rupture disks and safety valves guarantees a pressure inside the pipes lower than 10 bar.



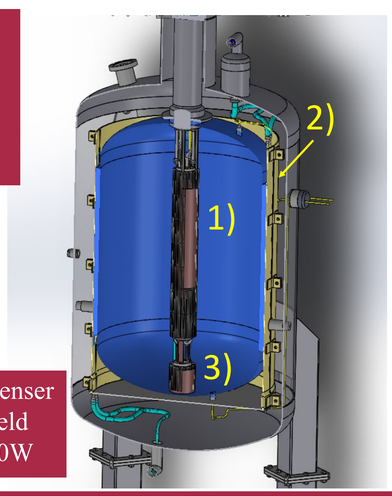


Storage Tank

- The storage tank can contain up to 500 kg of xenon gas at room temperature with a pressure up to 73 bar.
- A 500 W liquid nitrogen condenser (**1**) controls temperature and pressure together with a 200W electric heater (**3**) mounted on the bottom.
- Externally, in the vacuum gap, a LN_2 shroud (**2**) clamped around the inner vessel cools down the inner vessel (max power 1000 W).



A) High pressure cryo-valves
B) Connection to second laboratory
C) Liquid nitrogen plant connection
D) Venting valve inner vessel
E) Electric feed-through

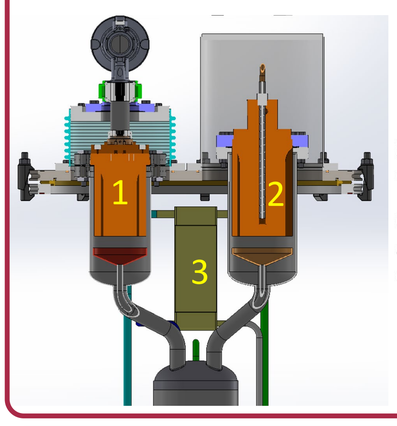


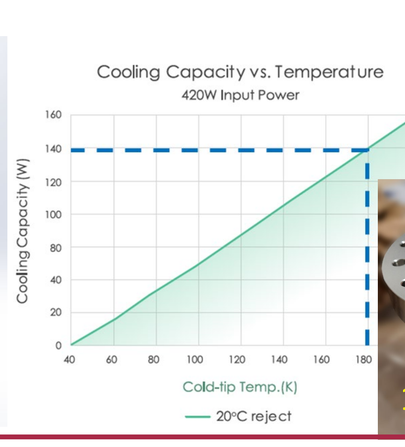
1) LN_2 inner condenser
2) LN_2 shroud shield
3) Inner heater 200W

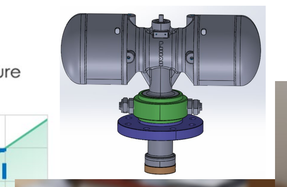
Cold Head & Cryocoolers

The two cold heads for the PTR (**1**) and the LN_2 cooled (**2**) are installed on the Cold Box.

- The PTR (**1**) provides a max power of 120-140 W @T=160-180 K (range of the liquid xenon temperatures @P=1-2 bar).
- The LN_2 cryocooler (**2**) provides up to 170 W. The flow is regulated by a flow-controller.
- The plate heat exchanger (**3**) facilitates the exchange of heat between room temperature GXe returning from the purification plant and LXe sent to the purification reducing the cooling power by almost 90%.

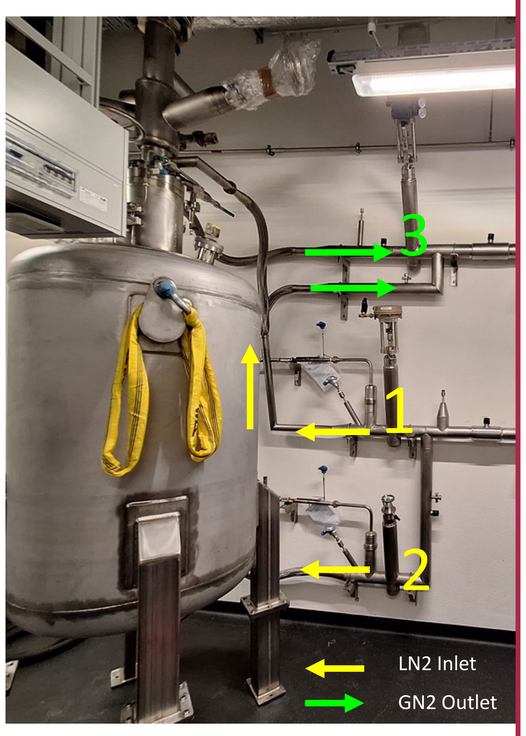






Liquid Nitrogen Distribution

- The LN_2 Plant can distribute the liquid nitrogen on the central condenser (**1**) or in the shroud (**2**) around the inner vessel.
- On the top of the LN_2 plant a cryogenic proportional valve (**3**) controls the outlet flow of the LN_2 in the inner condenser of the storage tank (ST).
- The inner pressure of the ST is stabilized by an algorithm using a set point pressure (SP=1.5-1.8 bar) and several small pressure thresholds. If the pressure change of ±5 mbar, ±10 mbar, etc…, the algorithm will increase the LN_2 flowrate, opening the valve (**3**) (5%, 10%, etc.), if the pressure increases (cooling). If the pressure drop below the SP, it will regulate, also by step, the power of the heater in the inner vessel of the storage tank.
- The shroud is used only to precool or heat the inner vessel and can only be operated manually. A vent valve regulates the constant flow of gas at the outlet.



Purification

- The purification system is connected directly to the warm side of the plate heat exchanger in the Cold Box and is located aside the storage tank in the basement technical room.
- In the initial phase only one getter by NuPure Omnia 2000 with max flow of 9 slpm of xenon will be used. The system is designed to mount up to two getters in parallel to reach the maximum flow of 20 slpm.
- A calibration box will be used to directly inject gaseous calibration sources into the xenon gas. The inlet/outlet valves are controlled remotely, enabling fully remote operations of XeLiPS.
- The double diaphragm pump by KNF, used as recirculation pump, has a flow range between 20-30 slpm at 50 Hz.