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GASEOUS HELIUM STORAGE AND MANAGEMENT IN THE CRYOGENIC SYSTEM FOR THE LHC

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Abstract

The Large Hadron Collider (LHC) is presently under construction at CERN. Its main components are superconducting magnets which will operate in superfluid helium requiring cryogenics on a length of about 24 km around the machine ring with a total helium inventory of about 100 tonnes. As no permanent liquid helium storage is foreseen and for reasons of investment costs, only half of the total helium content can be stored in gaseous form in medium pressure vessels. During the LHC operation part of these vessels will be used as helium buffer in the case of multiple magnet quenches. This paper describes the storage, distribution and management of the helium, the layout and the connection to the surface and underground equipment of the cryogenic system.

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Gaseous Helium Storage and Management in the Cryogenic System for the LHC

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The Large Hadron Collider (LHC) is presently under construction at CERN. Its main components are superconducting magnets which will operate in superfluid helium requiring cryogenics on a length of about 24 km around the machine ring with a total helium inventory of about 100 tonnes. As no permanent liquid helium storage is foreseen and for reasons of investment costs, only half of the total helium content can be stored in gaseous form in medium pressure vessels. During the LHC operation part of these vessels will be used as helium buffer in the case of multiple magnet quenches. This paper describes the storage, distribution and management of the helium, the layout and the connection to the surface and underground equipment of the cryogenic system.

1 INTRODUCTION

Cryogenic systems require storage facilities for the helium inventory. Medium-pressure storage is generally preferred to high-pressure storage which needs gas bags and recovery compressors with costly maintenance and also to liquid storage demanding a permanent re-liquefaction of losses. The LHC will make use of a large amount of medium pressure storage vessels distributed over the different sites, requiring a precise management of their interconnections.

2 HELIUM INVENTORY OF THE LHC

The LHC machine [1] is composed of eight sectors of 3.3 km length. Helium is mainly contained in the magnet cold masses which require a filling rate of 15 l/m of superfluid helium for enthalpy buffering as well as in one of the headers of the cryogenic distribution line [2] (header C) which requires a DN100 diameter for cool down and warm-up operation and which is filled with dense supercritical helium in normal operation. Figure 1 shows the helium inventory per sector. The total helium inventory of the whole machine is about 100 tonnes. The complete storage of this inventory would cost about 20 MCHF [3] and would require large facilities. For reasons of investment cost limitation and of environmental impact, it was decided to store only half of the inventory.

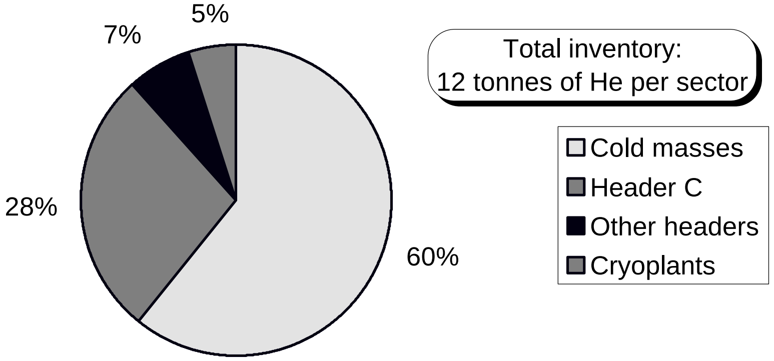

Figure 1 Helium inventory per sector

3 DISTRIBUTION OF THE HELIUM STORAGE

The cryogenic system of LHC has to re-use the existing LEP infrastructure which is constituted of forty vessels with a capacity of 75 m^3 each. These vessels with a diameter of 3 m and a length of 12 m have been installed in vertical position in the shadow of the buildings. To complete this storage, additional vessels have been ordered in two steps from European industry on the basis of competitive tendering. 12 vessels were delivered by Ferox (Czech Republic) and 38 vessels were contracted to Silva Matos (Portugal). These additional vessels of 250 m^3 capacity each, a length of 28 m and a diameter of 3.5 m, will be installed in horizontal position. All vessels are in carbon steel. The gaseous helium will be stored at a maxium working pressure of 2 MPa and ambient temperature. Table 1 shows the type and number of vessels distributed on the eight sites around the LHC ring.

At each point, four 250 m^3 vessels will be used as quench buffer in case of resistive transition of multiple magnets during LHC operation. These vessels must remain empty during normal operation and may only be used as storage capacity during shutdown. The remain vessels will be used as make-up gas storage for the cryogenic system. Helium at a temperature down to 10 K may be discharged into the quench buffer. In order to avoid cold spots on the carbon steel surface, the cold helium is diffused via a 26 m long stainless steel inlet pipe perforated with 41 holes of 5 mm diameter ; this diffuser is connected to the quench buffer wall via a stainless steel cold finger. The lowest possible temperature of the buffer walls during a total LHC sector quench is estimated [4] to -35 ^oC. The design temperature of the vessels made of fine grain carbon steel is -40 ^oC. Before manufacturing started, a Charpy impact test at -50 ^oC was performed on each shell plate as well as on the welding test plates.

Location	No. of vessels 75 m^3	250 m^3	Volume [m^3]	Mass of helium [tonnes]
Point 1.8	0	12	3000	9.1
Point 2	10	4	1750	5.3
Point 3	0	6	1500	4.5
Point 4	10	6	2500	6.8
Point 5	0	4	1000	3.0
Point 6	10	6	2250	6.8
Point 7	0	6	1500	4.5
Point 8	10	6	2250	6.8
Total	40	50	15500	46.9

Table 1 Distribution of storage vessels

4 STORAGE MANAGEMENT

4.1 Interconnection of Storage Aeras

Figure 2 shows the different interconnections between the storage areas around the LHC. For reason of available space at the different points, the storage vessels are not equally distributed. The easy accessibility for helium delivery to some points such as point 1.8 is also taken into consideration. A helium ring line interconnecting the different storage areas will be installed in the tunnel and the access shafts. Each sector refrigerator is directly connected to its make-up storage. At point 3 and 7, where no refrigerator is installed, make-up storage vessels are also available. Make-up storage can be interconnected by opening the V1 valves.

During a quench, helium leaves the cold environment via the interconnection box (QUI) and the return modules (QRLR) of the cryogenic distribution line ; the quench buffers are filled via the valves V2. The helium then returns to the sector refrigerator via the valves V3 or V4. They are also used during a partial LHC warm-up to store one part of the inventory in the quench buffers. In this case, no electrical powering of the adjacent sectors is allowed. To minimise the dead volume of the quench buffer, it is also possible to complete their emptying by connecting them via the helium ring line and the V5 valves to the low pressure (LP) of one refrigerator.

The hydraulic impedance of the helium ring line must not diminish the liquefaction capacity of the refrigerator during re-cool down of a sector, thus requiring a DN100 diameter pipe.

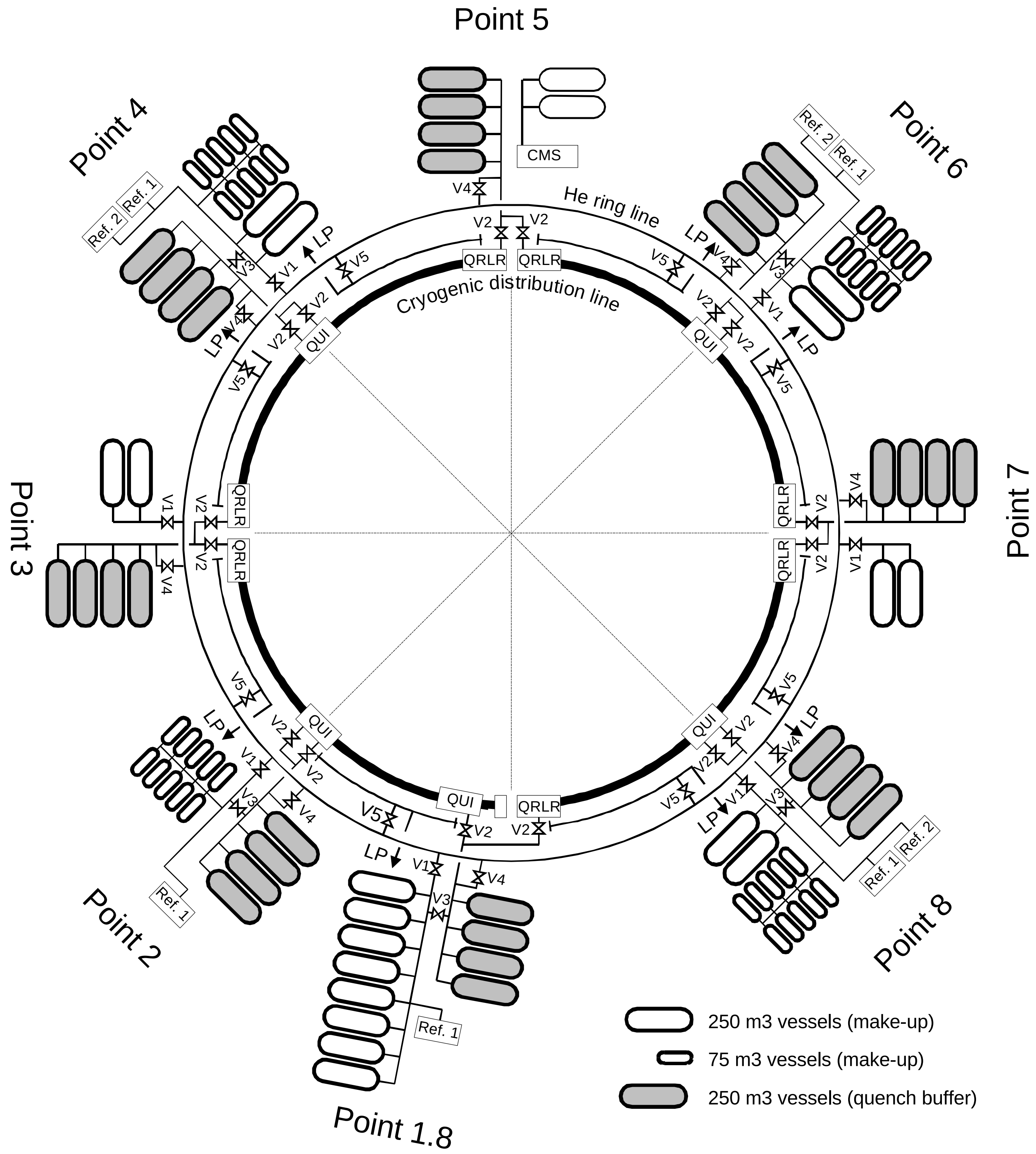

Figure 2 Interconnection of storage areas

4.2 Protection against Water Contamination

The compressor stations of the 4.5 K helium refrigerator plants [5] will be equipped with switchable full flow dryers located after the final oil removal system (ORS). The filling of the storage vessels will be made with helium taken at the full flow dryer discharge, guaranteeing water and oil-free helium in the storage. The compressor station of the 1.8 K refrigeration units [6] are not equipped with dryers. To avoid storage vessel pollution, the helium make-up discharge of these units is done via the warm compressor stations of the 4.5 K refrigerators.

Figure 3 shows the interconnection scheme of the compressor stations to the storage vessels. Clean gas is distributed to the different cryogenic components for circuit and volume purging.

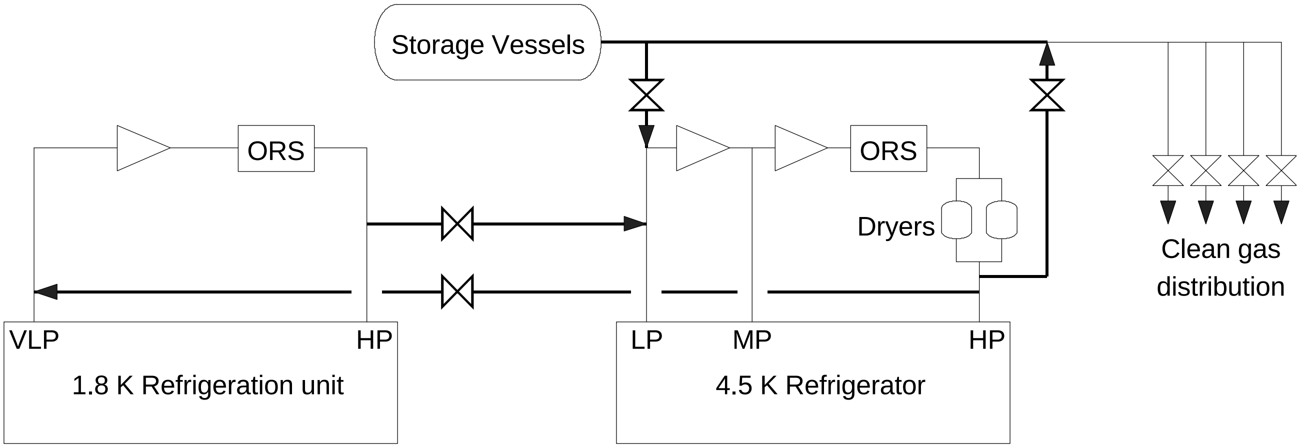

Figure 3 Interconnection of storage vessels to the compressor stations

5 PERIODIC CONTROL

The safety code which regulates the pressure vessel construction requires hydraulic pressure tests after manufacturing and normally after every 10 years of operation. This retesting is very heavy as it implies severe risk of contamination. A possible way to seek derogation from safety authorities consists of making use of acoustic emission monitoring during pneumatic tests [7]. A sound cartography is established during the first pneumatic test following the installation at CERN. At every retesting period, a new cartography is produced and compared to the original one in order to detect any mechanical deterioration. This new procedure is developed in collaboration with CETIM (France) who have the technical expertise.

6 CONCLUSION

For the LHC cryogenic system, medium-pressure storage will be distributed at the different points around the machine circumference. During normal operation, half of this storage will be dedicated to quench buffering. The remaining part will be used as make-up helium gas storage. Interconnection of the different storage areas and protection against contamination will be implemented allowing a flexible and safe management of the helium distribution. Acoustic emission monitoring of the pressure vessels, which seems to be promising to obtain derogation for the decennial hydraulic test, will be performed during pneumatic tests.

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