HL-LHC Nonconformity Report
LQXFA/B01 Leak Check

NC Description

Work Package	WP3	***Equipment***	HCQQXF_SC002-FL000001
Collaboration Contract Team	S. Feher, R. Rabehl, T. Vouris, J. Blowers	***Process***	Leak Check
		Inspector	J. Blowers

The combination leak check/pressure test of the CM01 after being cryostated,did not meet the leak rate specification of lower than1E-9 Torr-liter/sec (1.32E-9 atm-cc/sec). This is requirement #9 in "Requirements Specification for the Assembly of LQXFA/B/E/F", EDMS 1828585.

Prior to cryostating the cold mass was successfully tested under operational pressure (20 bar), See EDMS 2936376 (final report under preparation).

Documents used as reference	***Date of Issue***
Requirements Specification for the Assembly of LQXFA/B/E/F, EDMS 1828585	2023-06-09

NC Evaluation

In order to verify the fulfillment of the leak rate specification, on 20-Dec-2022 a leak check was performed with the cold mass and heat exchangers pressurized with Helium to MAWPs (cold mass was 20 bar absolute and heat exchangers to 4 bar absolute), while pulling a vacuum on the insulating vacuum space. The following are the steps followed:

- A vacuum was pulled on the insulating vacuum, and we worked to reduce the background to as low as we could. At the time of the leak check, this was the configuration of the test setup:
  - A pumping cart (turbo, roots blower, roughing pump) was connected to one end of the cryoassembly, and an Adixen ASM390 leak detector was connected to back the turbo pump when valved in. The MSLD reached a stable background of ~2.5E-8 atm-cc/sec.
  - A Leybold PhoeniXL 300 was connected to the middle of the cryoassembly, and it reached a stable background of <3E-9 atm-cc/sec.
  - The cold mass insulating vacuum and beam pipe were being pumped on (albeit these spaces were not at common pressure; they were pumped separately, and the MSLDs were only on the insulating vacuum).
- When it was determined that the insulating vacuum background was as low as we believed we could achieve, we pressurized the cold mass and heat exchangers to 20 and 4 bar absolute, respectively.
  - Cold mass reached full pressure at 15:25, and the Heat Exchanger circuit reached full pressure at 15:31.
- After reaching the maximum pressures we saw no change in the signals from either mass spectrometer for at least 16 minutes.
  - At 15:41, 16 minutes after the CM reached full pressure (10 minutes after the HX reached full pressure), the MSLD backing the turbo started to show a slow rise in signal. This signal increase is attributed to Helium permeating through the O-rings used internally to the cryoassembly A flexible hose assembly is used to complete the pressurization circuit between the cold mass and the non-IP end can. A metal seal was used at the connection between this flexible hose assembly and the Cold Mass. However, an elastomer seal was used at the connection between the flexible hose assembly and the end can.
  - At ~15:53, 28 minutes after the CM reached full pressure (22 minutes after the HX reached full pressure), the MSLD in the middle of the CA started to show a slow rise in signal.

The sensitivity to Helium for the Adixen ASM 390 is ~ 1E-12 atm-cc/sec, and for the Leybold PhoeniXL 300 is ~ 4.9E-12 atm-cc/sec.

In addition, in preparation for the cold test the cryoassembly was able to be cooled down to 1.9K without the need for any additional pumps to overcome any Helium leaks to the insulating vacuum.

Although the leak rate specification was not able to be directly verified, the lack of a signal rise on both mass spectrometers after the cold mass was pressurized with Helium, along with the experience from the test stand, we are confident that this cold mass is leak tight and should be accepted without needing to perform a second test.

See images below.

Figure 1 – Pumping cart being backed by Adixen MSLD

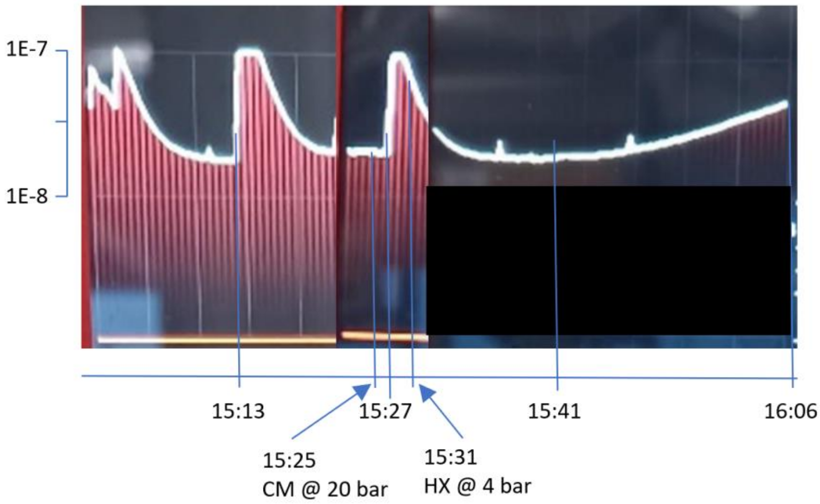
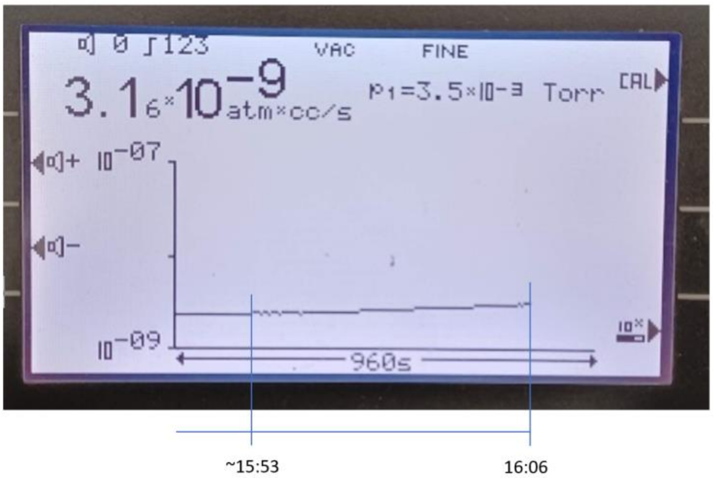


Figure 2 – "Stitch" of Pictures from MSLD at end of CA (pictured in Figure 1) – Timeline Below

Time	Event
15:13	Signal spike on MSLD at CA end from tightening a fitting on the GHe supply tubing
15:25	Coldmass reached 20 bar
15:27	Signal spike on MSLD at CA end from moving the GHe supply from the coldmass port to the HX port on the lead can
15:31	HX at 4 bar
15:41	Start of slow rise in signal on MSLD at CA end (signal ~2.5E-8)
~15:53	Start of slow rise in signal on MSLD in middle of CA
16:06	Signal ~5E-8 on MSLD at CA end 3.1E-9 on MSLD in middle of CA



Figures 3 – signal taken at 16:06 from MSLD connected to middle of CA – slow rise started ~15:53

Context regarding the use of two MSLDs:

While we were working to reduce the background we were troubleshooting various small leaks (not in the cold mass or cryoassembly, but in various ports or external connections). A couple of leaks that we were not able to fully resolve at the time were from the gate valve and valve block on the turbo cart and the MSLD connection to it, which was preventing the background on that MSLD from getting back down to a prior low of 4E-9. In light of this, it was decided to connect a second MSLD into the test setup (in the middle), and that was the configuration at the time it was decided to pressurize the cold mass and heat exchangers.

Concerning root cause and preventive actions:

Although we are not able to point to a single root cause for not being able to achieve the desired Helium background, we do know that it was, in part, due to small leaks in the test setup which we were not able to fully address at this time. We also concluded that future leak tests should use improved pumping equipment (equipment that is more capable of cleaning up the background), and so a new pumping cart system has been ordered. For tests of future coldmasses we expect to use the new pumping cart, and we plan to use only one MSLD so that the signal is not split.

Documents used as reference

Evaluation team: S. Feher, R. Rabehl, T. Vouris, J. Blowers

Decision

Critical (Impact 4,5) ☒		**Non-Critical (Impact 1,2 or 3)** ☐	

Repair ☐	Regrade ☐	Scrap ☐	Return ☐	Concession ☒

Collaboration manager /WPE/WPL/PL	*G. Apollinari* *S. Feher* *H. Prin* *E. Todesco*	***Date***	27.09.2023

Based on the provided data, VSC would not recommend the installation of the cold mass LQXFA/B01 in the LHC tunnel without further tightness confirmation. On the other hand, there is no indication that a helium leak exists in the range that would be detrimental to short-term operation at the IT String. Therefore, the NCR is closed as concession.

The results of the leak test at CERN after the phase II cryostating shall be added to this NCR. It is noted that in any case this cold mass will be reworked to cure the QH issues, therefore in the present form it cannot be installed in the tunnel.

PREVENTIVE ACTIONS

For the future cold masses (starting from CM02) the leak test procedure is to be shared with CERN/TE-VSC before performing the tests, and the results are to be shared immediately such that corrective actions (if any) can be applied in a timely manner to avoid this problem in future cold masses.

NCR Closure

Date of re-inspection	20YY-MM-DD	***Inspector***	N. Surname

This section is Not Applicable

Agreed measurements have been successfully implemented: Yes ☐ No ☐ Not applicable ☒

Non-Conformity Closed: Yes ☐ Yes with remarks ☒		***Date Closure***	20YY-MM-DD

Inspector	***Supplier***	***Collaboration manager/WPE/WPL/PL***
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