THE LHC EXPERIMENTAL BEAM PIPE NEON VENTING, PUMPING AND CONDITIONING

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Abstract

The experimental vacuum chambers of the four LHC experiments (ATLAS, CMS, LHCb and ALICE) are mechanically optimized in order to be transparent to particles. In order to grant their mechanical stability and to avoid any overstress, every time there is a request for detector opening or closing and for working in the vicinity of the vacuum chamber, the experimental beam vacuum chambers are vented to atmospheric pressure. Since the LHC start up a safety procedure has been applied to mechanically secure the four experimental beam pipes during each long technical stop. Ultra-pure neon was used to preserve at best the NEG pumping efficiency. Up to now 18 neon injections and pump down have been performed without detecting any reduction of the NEG efficiency.

This paper describes the Gas Injection System performances and the main points of the venting and pumping procedure. Details of the experimental beam pipe vacuum recovery and conditioning are presented for each of the four LHC experiments.

INTRODUCTION

The experimental chambers and supports are mass-optimised to maximise transparency to particles and the maximum differential pressure that the chamber wall can withstand is about 1.5bar. They are hence fragile, particularly when under vacuum. In several occasions the operators may need to move objects or work around the chamber *i.e* during detector opening and closing, during bakeout removal or detector maintenance. In those cases it is necessary to bring the beam vacuum chamber to atmosphere, while preserving at best the NEG characteristics. If during such occasions the chambers are left under vacuum, a small knock could lead to buckling, adding several weeks, up to months additional shutdown time, due to the necessity of reactivating the NEG surfaces, *i.e.* baking the experimental chambers.

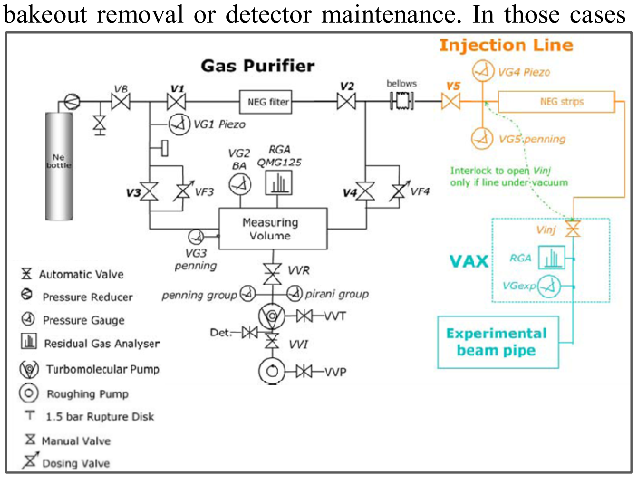

Figure 1: Schematic of the Gas Injection System for ATLAS, CMS and ALICE.

A Gas Injection System (GIS) [1] was designed for the four LHC experiments to inject neon into the chambers and pump it out without contamination. In order to avoid losing the effect of the bakeout, the venting is made with ultra-pure neon.

GIS LAYOUT

The Gas Injection System consists in a gas purifier and an injection line. The gas purifier is a UHV system, bakeable up to 250°C; it was conceived identical for the four LHC experiments with some small adjustments. [2]. A schematic view of the GIS is shown in Figure 1.

Gas Purifier

Each gas purifier is provided with:

- A 99.999% Neon bottle.
- A rupture disk of 1.5 bar, positioned closed to the neon bottle. Next to the rupture disk, a piezo manometer (VG1) can be used to check the pressure during injection and stop the process.
- A filtering stage constituted of one NEG cartridge (SAES model PS11FT400-S52, Integrated Filter 0.003 micron, metal), included between 2 manual valves (V1 and V2). The filtering is guaranteed if the gas flow does not exceed 20 bar•l/s, which is always the case given the small conductance in front of the filter.
- A measuring volume, *i.e.* a volume equipped with a Bayard Alpert gauge (VG2) and a residual gas analyser Balzers QMG125. The pipelines to the measuring volume have two valves in parallel, (V3 and V4) and leak valves (VF3 and VF4).
- A pumping group of LHC type, with a pneumatic inlet valve (V6).

Table 1: Summary of the LHC Experiments Beam Pipes Parameters and their Relative Ne Injection and Pumpdown

	Volume [l]	Neg Surface [m^2]	Injection line (ϕ 60mm) length [m]	Pumping Speed at VAX [l/s]	Injections and Pump Down	Injection Time [h]	Pump Down Time Up To 10^{-8} mbar [day]
ATLAS	300	9.20	10	1	2	2	1
ALICE	900	13.9	6	3.6	3	7	1
CMS	800	17	6	3	4	4	2
LHCb	2235	10.5	10	VELO (see text)	9	12	3

Injection Line

Depending on the GIS location with respect to the beam pipe the injection line is custom tailored to each experimental region. SAES NEG strips, type 707, are installed over the whole length to maintain the line the cleanest possible and decouple the purifier from the experimental beam chamber. The piezo gauge (VG4) and the penning gauge (VG5) are used to monitor the line pressure and the NEG strip conditioning. Since the maximum Ne pressure in the beam vacuum chamber, at the end of the injection, shall not exceed 1.5bar, a rupture disk is installed in the GIS to prevent overshooting this value.

NEG Cartridge: Ne Purification

The composition of the purest Ne available on the market is Ne at 99.999%. The volume to be filled at atmospheric pressure is of the order of 0.3 – 0.5 m^3 and at atmospheric pressure this corresponds to a total amount of impurity of about $4{\cdot}10^{-3}$ mbar·m^3. Therefore the filter used in the pure gas injection system was selected to remove getterable gases found in a Ne bottle (H_2, N_2, CO, CO_2, O_2 and H_2O) to a maximum acceptable impurity level of 1% NEG contamination. Those levels are $\leq$ 0.08 ppm for CO and CO_2 and $\leq$ 0.82 ppm for O_2 and H_2O. In addition the filter has a capacity higher than $4{\cdot}10^{-3}$ mbar·m^3 and it is reusable and easy to reactivate.

Software

The system is equipped with a touch panel and a semi-automatic control system to operate the pumping equipment, the gauges functioning and the remote valve opening and closure. For safety reason no remotely operation of the baking system was foreseen. The system is connected with the LHC monitoring system (PVSS), which records the instrumentation signals and the system state (valve positions, pump state, temperature, etc.).

Interlocks

To avoid that the interface valve between the pure gas injection system and the experimental beam chamber opens before the system is ready to inject and/or to pump, the reading from the VG5 penning gauge is used as an interlock for the opening of the VAX injection valve (Vinj in Figure 1). In the event of a general power cut, all pneumatic valves, both on the beam line and on the GIS will close and the GIS pumping system will be vented to air.

NEON INJECTION PROCEDURE

Amongst the possible noble gas species that can be employed, neon is the choice of preference for the following reasons:

- helium is used for leak detection. The small amount that may be left after pump down would reduce the sensitivity of the leak check.
- Argon is used as indicator of air leaks during NEG activation, since NEG pumps very efficiently other components like oxygen, nitrogen and carbon dioxide.
- As for helium, a small amount of argon that may be left after pump down would reduce the sensitivity of the leak monitoring.
- Krypton and xenon have a too high cross-section for beam-gas interactions, so that even small traces would lead to high background.
- Neon has a low mass and does not affect leak detection.

A standard procedure has been adopted to prevent any Ne contamination during injection and pump down.

The GIS preparation consist in a complete leak detection, residual gas analysis (RGA), bakeout, NEG cartridge activation at 400°C , system cool down and RGA final scan. The total required time is 5 days.

Depending on the beam pipe portion to be filled, the sector valve between the GIS injection line and the beam pipe have to be opened and secure opened during the complete procedure. The NEG filter is kept at 400°C during the entire injection.

The operators follow the pressure rise on the piezo gauge of the injection line until the pressure reaches 980 mbar. The injection time varies for each experiment and it is given in Table 1.

NEON PUMP DOWN PROCEDURE

For all the LHC experiments except LHCb, the neon is pumped down through the GIS pumping system, bypassing the NEG filter. Despite the original requirement to isolate the pumping system in case the rotational speed falls below 80% of its nominal value, accurate test demonstrated that during the first fase of pumpdown, the turbopump can reduce its turns up to 5/10% without any backstreaming danger [3].

In the past, accumulation stages were performed, during the pump down, to estimate the remaining neon degassing value and the maximum detectable leak rate in the vacuum chambers [4]. The accumulation stages study demonstrated that either providing a constant pumping or a discontinued one (usually during daytime for safety reason) the total pumping time is the same.

LHC EXPERIMENTS DETAILS

The criteria used to select the GIS location in each cavern were: a minimum radiation level during operation, a residual dose compatible with human intervention for several hours and an injection line conductance not so low to affect significantly the pumping time.

ATLAS: in IR1, the gas purifier is located on the concrete shielding around the TAS (6th floor), on the left hand side of the cavern. It is connected to the ATLAS experimental beam vacuum chamber to the left.

ALICE: the gas purifier in IR2 is located in the experimental cavern close to the muon shielding support, next to the LHC tunnel, and is connected to the ALICE experimental beam vacuum chamber through the right VAX station.

CMS: the Gas Injection System in IR5 is connected to the CMS experimental beam vacuum chamber to the left VAX station via an injection line that goes through the concrete shielding box around the TAS.

LHCb: the Gas Injection System in IR8 is located on the "balcony" platform, along the wall next to the VErtex LOcator and is connected to the LHCb experimental beam vacuum chamber to the VELO vessel, with a line that branches off to fill both detector and beam vacuum chambers. A system of valves and conductance ensures that during the injection the pressure difference between the two volumes is kept below 5 mbar, to avoid breaking of the thin foil between the beam vacuum and the VELO detector. In the LHCb experiment, the injection speed is limited by the maximum pressure difference across the VELO RF foil, and the total fill time goes up to between 8 and 12h. Differently from the other experiments, the neon is pumped directly via the VELO pumping system.

LHC EXPERIMENTS STATUS

As listed in Table 1, up to now 18 neon injections and pump down have been performed without detecting any reduction of the NEG efficiency. Figure 2 shows the pressure decreasing in the four experiments beam pipes after the Ne injection carried out during the shutdown at the end of 2010. The pressure recovers to the initial value in about 4-5 weeks.

To keep on checking the reliability and fail-safety of the GIS system and improve the operating procedures, the GIS systems are constantly tested on a mock-up system 20 m long, with NEG coating and equipment such as gauges and ion pumps as used in the room temperature sectors of the LHC accelerators.

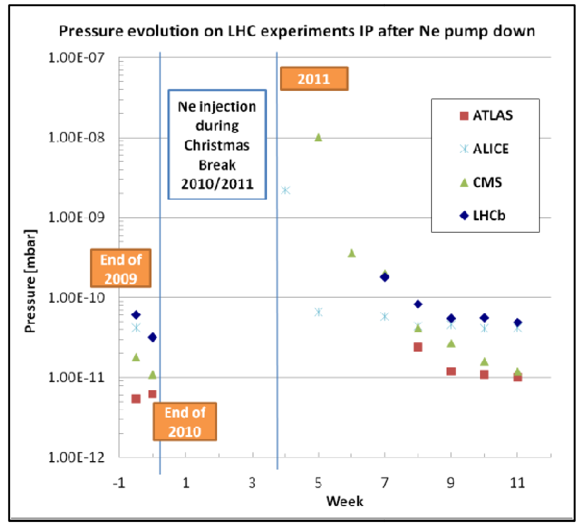

Figure 2: Pressure evolution after the Shutdown of 2010.

Laboratory test have been carried on to study the neon impact on the ion pumps. It was demonstrate that all the tested ion pumps could stand a neon quantity of 2 mbar·l without recording any variation of their pumping speed. Those studies confirmed that it is possible to switch the ion pumps back on at a pressure level lower than $2 \cdot 10^{-9}$ mbar.

Every shut down time is precious for the maintenance and the upgrading of the experiments. Therefore, to maximize the available working time in safety condition around the experiments during a long shutdown or a Christmas break, the GIS operations time required for the preparation, the Ne injection and the pump down time has been carefully planned and optimized: the GIS is normally check, maintained and baked during a previous technical stop. Two teams working in parallel are able to perform the neon injection for the four experiments in two weeks. At the end of the shutdown, as soon as the detectors are closed, the beam pipe is ready for operation one week after the pump down started.

The project of adding a second pumping station to the ATLAS and CMS experiments is under study to increase further the available working time around the vacuum beam pipe.

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