CHAPTER 28

VACUUM SYSTEM FOR LHC TRANSFER LINES TI 2 AND TI 8

28.1 INTRODUCTION

The Vacuum Group is responsible for the design, manufacture and installation of all the vacuum components of the transfer lines in collaboration with the Beams Transfer Group. The main components are the drift-space and magnet vacuum chambers, bellows, pumping ports, supports and vacuum instrumentation. The work, including the installation of the components in the tunnels has been carried out in collaboration with the Budker Institute of Nuclear Physics in Novosibirsk (BINP, Russia).

The requirements and layout of the vacuum system and the calculations of the pressure profile expected over two standard half-cells (~ 60.6 m) are presented below.

28.2 VACUUM REQUIREMENTS AND BASIC PRINCIPLE

The dynamic pressure, i.e. the pressure in presence of beam, in the LHC transfer lines is equal to the static pressure because there is only a single beam passage and as a result of the low beam losses expected. Therefore, the design pressure has been fixed to optimise the lifetime of the pumps.

About 50 ion pumps in each transfer line will be use to achieve a high vacuum ($<10^{-5}$ Pa), a value which is low enough not to deteriorate the lifetime of ion pumps. These pumps have been chosen mainly for their high reliability, simplicity, cleanliness and because their currents give indications on the local pressure. They also provide reliable interlocks for the sector valves in case of pressure rises. The roughing of the vacuum system down to 10^{-3} Pa before switching on the ion pumps is done with mobile turbomolecular pumping stations.

28.3 LAYOUT AND PRESSURE PROFILE

Each transfer line has about 96 half-cells, composed of one quadrupole magnet, a beam position monitor, a dipole corrector, a pumping port and 4 dipoles.

The vacuum sectors are about 450 metres in length and start immediately after the beam separation in the TT60 or TT40 transfer lines. They end immediately after the beam dumps (TED) in the downstream part of the transfer lines, about 50 meters upstream the injection into the LHC main ring. Each vacuum sector has three roughing valves for the connection of both the mobile pumping stations and leak detectors and one combined Pirani and Cold Cathode gauge (Type BALZERS FullRange).

The ion pumps, with an effective pumping speed of 20 l/s, are installed every half-cell at the bottom of the pumping ports. For cost reasons, only half of them (one in two is skipped) have been connected to a power supply. The pumps which are not powered will serve as spares.

Fig. 28.1 shows the pressure profile expected over two half-cells (60.6 m) with an ion pump powered every two half-cells and assuming an outgassing rate of 4×10^{-7} Pa.m/s (4×10^{-10} mbar.l/s.cm^2) after 24 hours of pumping. This outgassing is derived from the outgassing measurements made on the first batch of dipole chambers received at CERN.

The outgassing, which is mainly composed of water (unbaked system), will decrease with a slope of t^{-1} where t is the time in hours. An average pressure of 3×10^{-4} Pa will be achieved after about one week of pumping, assuming the previous pumping sequence.

The measurements obtained during the installation of the TI8 transfer lines showed a faster decrease of the pressure. A pressure in the low 10^{-5} Pa has been achieved after about 2 weeks of pumping.

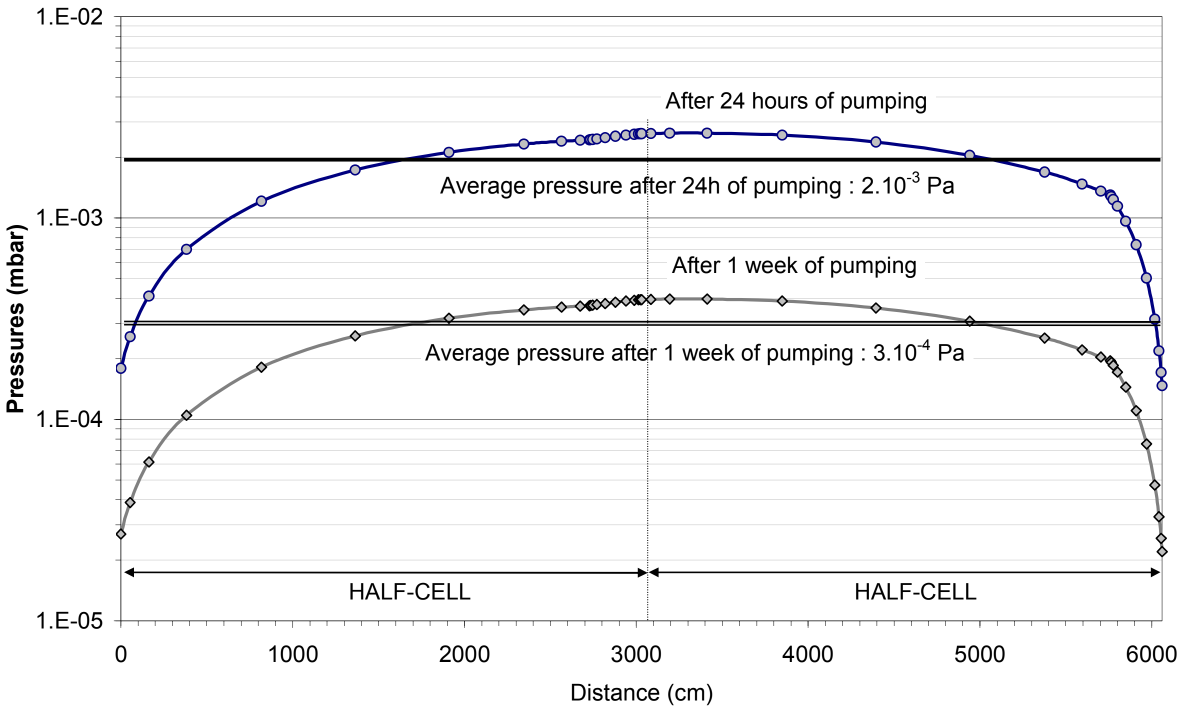

Figure 28.1: Pressure profile expected over two half-cells (60.6 m) with an ion pump powered every two half-cells and assuming an outgassing rate of 4x10^{-7} Pa.m/s (4x10^{-10} mbar.l/s.cm^2) after 24 hours of pumping.

28.4 VACUUM COMPONENTS AND VACUUM CONTROL SYSTEM

About 830 bellows, 690 chambers for magnets (dipoles, quadrupoles and correctors), 350 drift-space chambers and 180 pumping ports compose the vacuum system of the two LHC injection transfer lines. These two thousand pieces will be interconnected using 2000 coupling connections with chain clamps and aluminium gaskets.

28.4.1 Magnet Vacuum Chambers

The beams circulate in stainless steel vacuum chambers with a low magnetic permeability. The vacuum chamber section varies depending on the position along the beam line.

About half of the quadrupole magnets have a circular aperture, the other have an elliptical chamber which can be oriented horizontally or vertically. Fig. 28.2 shows the different types of apertures used for the transfer lines.

The dipole and dipole corrector magnets have elliptical or nearly rectangular chambers. To maximise the beam aperture, the dipole vacuum chambers are installed in the magnets and compressed while welding the two half yokes together.

28.4.2 Drift-space Chambers and Interconnections

To simplify the alignment of the straight sections, the drift-space chambers are circular pipes with an inner diameter of 60 mm (Fig. 28.2), much larger than the beam aperture required.

All chambers, bellows, pumping ports and all other equipment of the beam lines are interconnected using quick-disconnect conical flanges (KF63), chain clamps and aluminium gaskets.

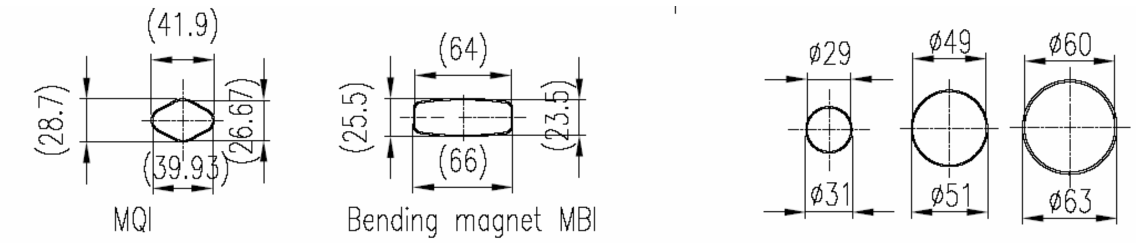

Figure 28.2: Section of the vacuum chambers in the SPS and LHC Transfer lines. In the transfer lines, the quadrupoles are called MQI, the dipoles MBI.

28.4.3 Vacuum Control and Pressure Monitoring

All the sector valves, ion pumps and gauges will be controlled using the Vacuum PVSS interface which is used for the PS and SPS machines. This application, which is being upgraded for the LHC, allows pressure monitoring and data storage. All actions requested like closing/opening of sector valves, switching ON or OFF of ion pumps are recorded for post mortem analysis. The pressures measured by the gauges and ion pumps are recorded once per minute and this gives indication of the status of the vacuum system, allows small leaks to be identified from trends and will be used for post mortem analysis if a huge leaks induces a stoppage of all ion pumps. Figs. 28.3 and 28.4 show the main page of the Vacuum PVSS application and the synoptic and sectorisation of the LHC injection transfer lines, respectively.

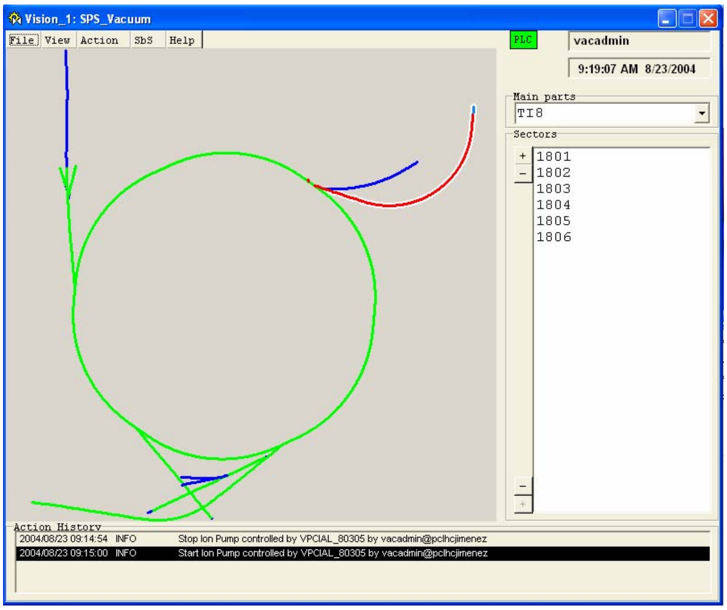

Figure 28.3: Main page of the Vacuum PVSS application which allows the access to the control interfaces for the SPS and LHC injection transfer lines.

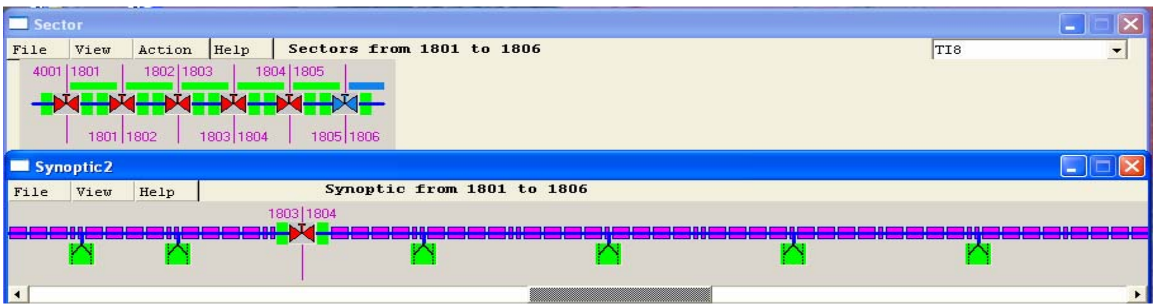

Figure 28.4: Vacuum sectorisation and mechanical synoptic of the LHC injection transfer line.