CHAPTER 20

THE INTERNAL BEAM DUMPING SYSTEM

20.1 SYSTEM DESCRIPTION

There are three main ways in which the SPS internal beam dump will act:

- Firstly, the internal beam dumping system is automatically triggered at the end of each SPS beam cycle in order to remove any remaining beam from the machine after the last extraction and before the magnets begin to ramp down ready for the next beam cycle.
- Secondly, the internal beam dumping system is automatically fired in case of emergency conditions or interlocks generated by other equipment. Poor beam quality or abnormal beam losses can also provoke an emergency beam dump.
- Finally, the beam dump may be deliberately activated at a specific time in the running SPS beam cycle for reasons which include machine tuning and special machine development tests.

The system consists of a pair of kicker magnets which are used to deflect the circulating beam onto an absorber built around the vacuum chamber. Two absorber blocks are installed: one (TIDH – Target, Internal Dump, Horizontal deflection) is optimised to dump the beam at energies up to 30 GeV, while the other (TIDV– Target, Internal Dump, Vertical deflection) is used at energies above 100 GeV. The beam cannot be cleanly dumped in the energy range 30-100 GeV. In order to reduce the maximum energy density deposited on the TIDV, the beam is kicked vertically downwards and swept in a horizontal sine-like pattern to provide beam dilution.

20.2 RATIONALE FOR A DESIGN UPGRADE

The original configuration of the TIDV remained practically unchanged over more than twenty years of operation in spite of a substantial increase in the beam intensities routinely accelerated in the SPS. The original SPS design [1] was for 1×10^{13} protons per cycle with initial maximum beam energy of 300 GeV. Intensities of almost five times this have been routinely accelerated to 450 GeV.

The total intensity of the nominal LHC beam in the SPS is not as high as the fixed-target beam used during operation for the west area neutrino facility and foreseen for CNGS operation. The nominal LHC beam has a total intensity of 3.3×10^{13} protons. However, while the fixed-target beam fills 10/11th of the SPS circumference, the LHC beam fills just 1/3rd. The peak intensity therefore reaches twice the fixed target case. The situation for the ultimate LHC beam in the SPS is even worse. The ultimate LHC beam in the SPS has a total intensity of 4.9×10^{13} protons compressed into 34% of the circumference. A fixed target beam having the equivalent peak intensity would require a total intensity of $\sim1.3\times10^{14}$ protons. The sweeping system for the internal beam dump was designed to spread the energy from a beam which essentially filled the circumference of the SPS. Compressing the beam into a smaller section of the circumference reduces the efficiency of the sine-like sweep pattern.

The core of the original TIDV consisted of a water-cooled, slotted block of Al_6Cu aluminium-alloy, forged and heat-treated for maximum strength. The block was centred in a water-cooled, Cu/Cr/1Zr copper alloy cylinder, forged and heat-treated. The copper was machined and electron beam welded from two half cylinders and formed an integral part of the SPS Vacuum Chamber with passage for both injected and circulating protons. The core assembly was mounted within two water-cooled, cast iron shielding blocks.

Energy deposition induced by particle cascades produces local heating and thermal stresses in the absorber. Simulations [2] showed that the ultimate LHC beam in the SPS would cause an unacceptable temperature rise in the original aluminium core. For this reason the TIDV was redesigned [3] to accept a proton beam of LHC injection energy and intensity. For the new design a more balanced distribution of energy deposition [4] is achieved within the core. Simpler in conception, the new core consists of a number of 2μm-Ti-coated graphite blocks [5], pressed into the lower half of a welded, standard industrial OFE, copper cylinder. Immediately downstream of the graphite are common aluminium-alloy blocks, followed by a length of copper, and a rearguard of tungsten. As a precautionary measure, thin 100µm-thick titanium foils are affixed to the graphite blocks, to prevent possible migration of graphite particles within the vacuum chamber. The copper is water-cooled. The cast iron shielding is unchanged, as is the sweep pattern of the dumped beam. Graphite (about 90 kg) is used in this instance within the SPS vacuum chamber, for the first time. Cross-sections of the core of the TIDV are shown in Fig. 20.1, while Fig 20.2 includes a longitudinal cut through the core showing the different absorber materials: carbon, aluminium, copper and tungsten.

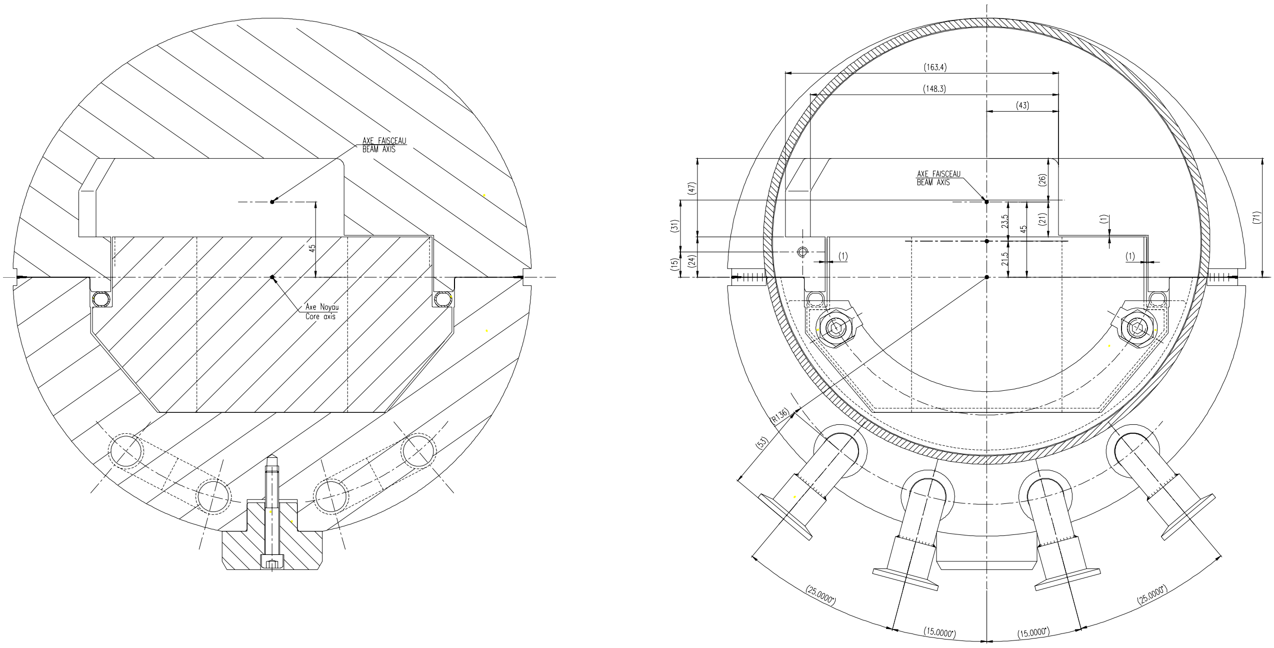

Figure 20.1: Cross-section and front-view of the TIDV core

20.3 ASSEMBLY AND TESTING

Prior to the selection of a type of graphite with optimum mechanical, thermal, and vacuum properties, several varieties were tested for the bake-out and degassing behaviour [6]. The most suitable graphite was considered to be the type 2020 PT.

The core components were assembled in a clean room with all due precaution and the copper half-cylinders were clamped rigidly to acquire the necessary constraint for good thermal contact as well as for precise weld preparation. The clamped assembly was dispatched to a contractor for electron beam welding of the copper cylinders and vacuum end-flasks.

Upon recuperation by CERN, the core was out-gassed at 150 °C for 24 hours using a pressurised hot water system and vacuum tested. Out-gassing and vacuum figures proved to be perfectly acceptable, with respect to SPS standard requirements [7]. The core was then assembled within the cast-iron shielding blocks. A further out-gassing period was then undertaken with the pressurised hot water circulating system.

20.4 INSTALLATION AND COMMISSIONING

The first TIDVG beam dump was installed in the LSS1 during the shut down of November 1999. In January of the year 2000, the dump was brought to its position in the tunnel, connected to the vacuum system, and subjected to about 60 hours of pumping and out-gassing tests. By the end of March and prior to machine start up, a pressure of 1.5×10^{-8} mbar was measured in the proximity.

Systematic dumping tests began with low beam intensities, increasing over a couple of weeks to reach $\sim9\times10^{12}$ protons per cycle at 450 GeV. The effects of this repetitive dumping were reflected by a steady increase in vacuum pressure to nearly 10^{-6} mbar (Fig. 20.3), followed by steady recovery with beam off.

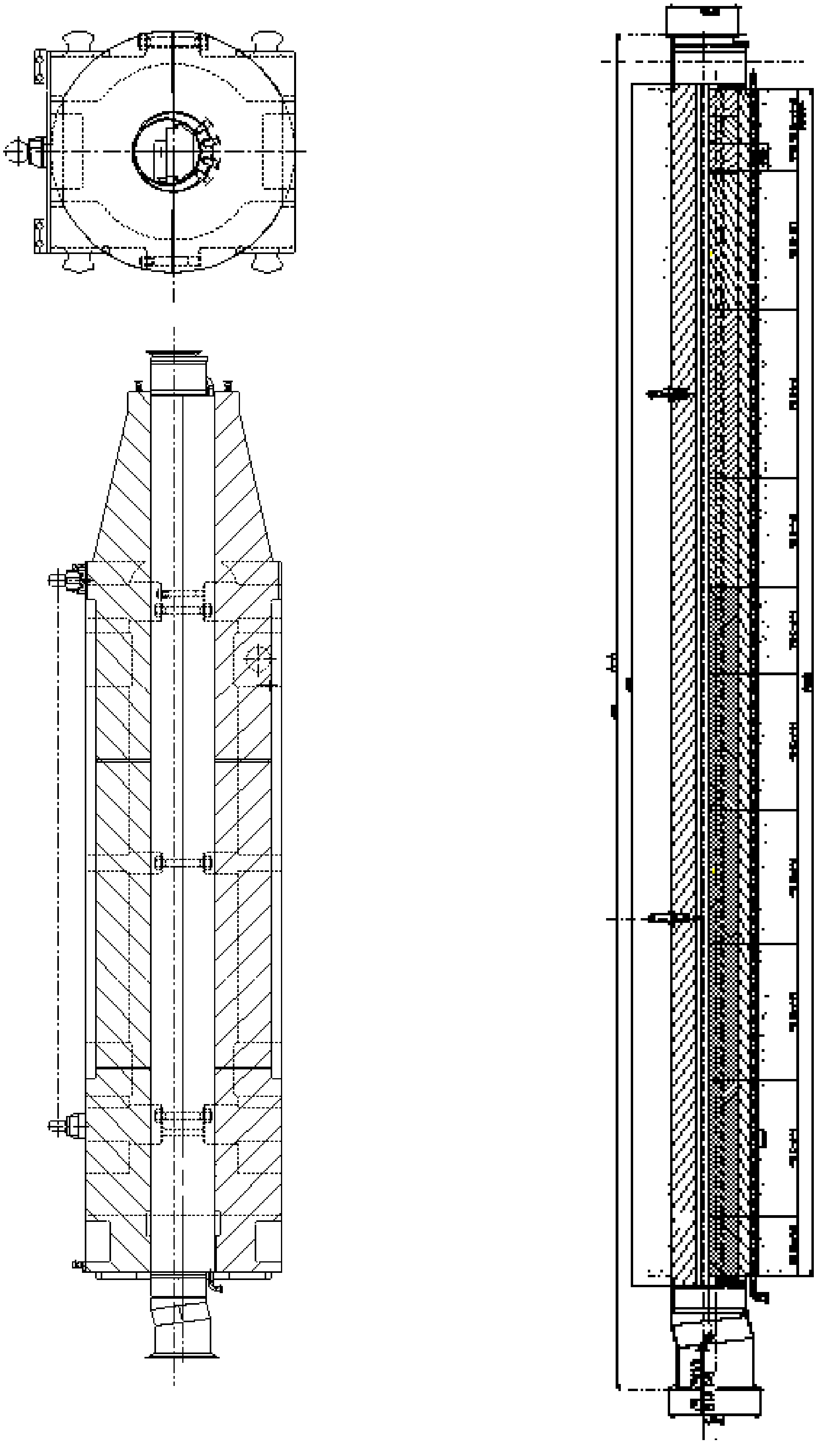

Figure 20.2: Schematic views of the TIDV absorber with a longitudinal cross-section of the absorber core.

Testing continued with a series of ten successive dumps of 2.5×10^{13} protons during the period while the machine set up the required intensities for fixed-target operation [8]. During this test the copper surface temperature rose to about 60°C and the local vacuum pressure to 9.2×10^{-6} mbar. In effect, the core was being baked-out and de-gassed as a result of the high temperatures generated by the deposited beam and vacuum recovery became more marked with successive dumping.

After about 4 weeks of operation the normal SPS physics run was underway, with occasional beam dump triggers under normal operational conditions. With the beam off, the vacuum pressure was recorded at 9.8×10^{-9} mbar. After five months of continuous operation, the pressure profile with beam off indicated an all time record for any TIDV, of 2.8×10^{-9} mbar (see Fig. 20.4). The pressure increases to around 1×10^{-8} mbar under normal operation conditions, with an intensity of about 3×10^{12} protons dumped at 450 GeV (Fig.20.5).

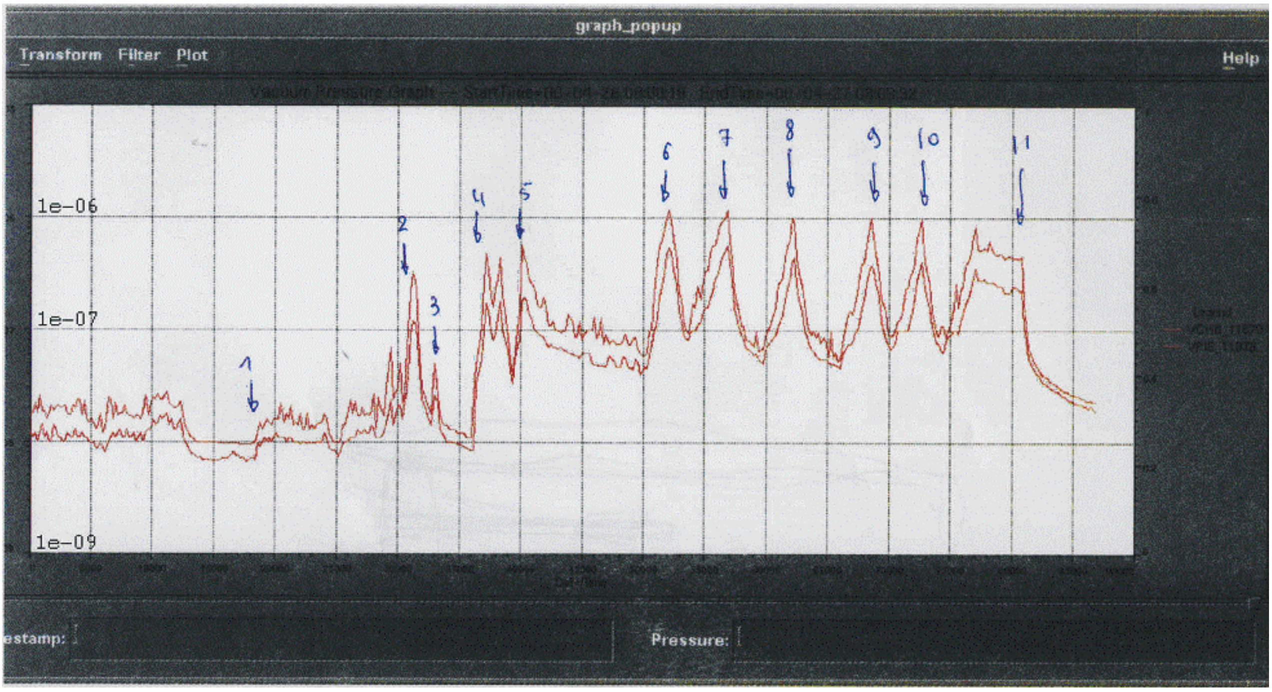

Figure 20.3: Systematic dumping of 9×10^{12} protons at 450 GeV on 27th of April 2000

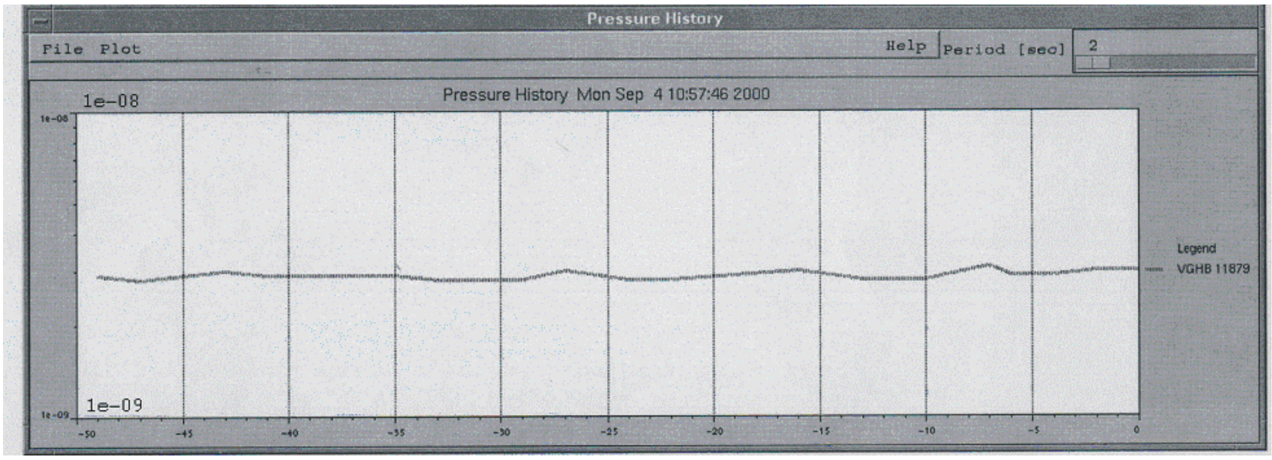

Figure 20.4: Vacuum pressure with beam off after five months of continuous operation

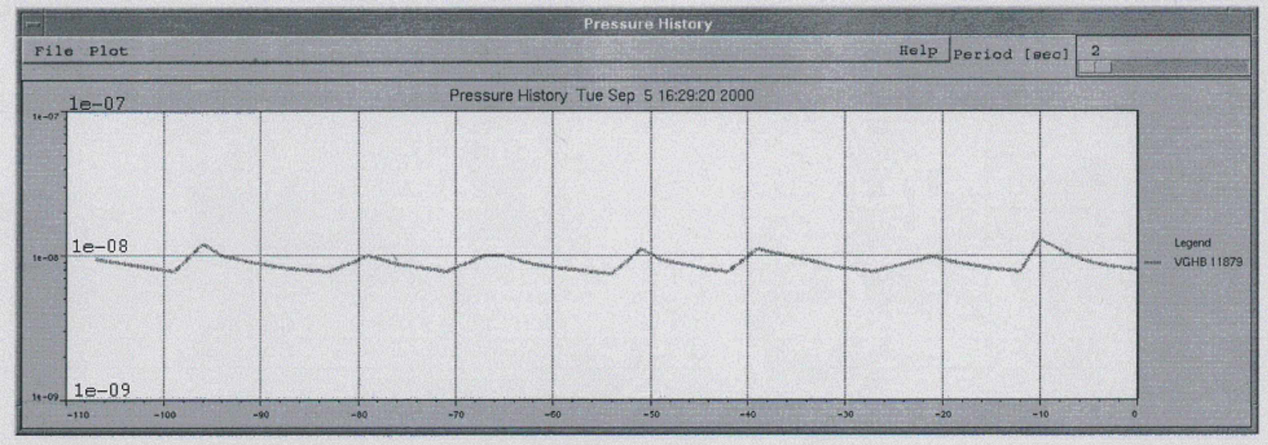

Figure 20.5: Normal vacuum conditions (~3×10^{12} protons at 450 GeV) after five months of continuous operation

REFERENCES

[1] The SPS Conceptual Design Report, "*The 300 GeV Programme*", CERN/1050, 1972.
[2] S.Péraire, "*Décharge sur le dump interne TIDV du SPS de faisceaux destines au LHC*", CERN SL/Note 96-15 (BT/TA), Feb 1996.
[3] SL drawing SPS 8034 41 0065 0.
[4] J.M. Zazula & M. Ross, "*Transient Temperature Distributions Effected by Dumping the SPS Beam (LHC Injection Regime)*". CERN SL/Note 95-91 (BT/TA).
[5] S. Calatroni, H Neupert & W. Vollenberg, "*Production of Titanium coatings on Graphite Blocks*", CERN EST SM Dec 1999.
[6] R. Cornali & J. M. Jimenez, "*Measure du Taux de Degazage de Divers Types de Graphites*", LHC-VAC/RC Vacuum Technical Note 99-08 Juillet 1999.
[7] G. Mathis & K. Weiss, "*Test Beam Dump SPS n°2, après réparation des quatre angles chez Techmeta*", 23-11-1999.
[8] M. Ross, "*The Millenium Dump: TIDV Commissioning –April 2000*", SL-Note-2000-050-BT, 2000.