CHAPTER 23

GENERAL SERVICES

23.1 WATER COOLING

23.1.1 Demineralised Water Systems

The demineralised distribution system in TI 2 and TI 8 is mainly used for cooling the magnets coils and the water cooled cables installed in the tunnels [1,3]. Additional cooling must also be provided for the beam stoppers, or TED, in each line.

Primary water is supplied from the LHC cooling towers (SF2 and SF8) and acts as the heat sink for the demineralised water. The primary water is cooled down by these cooling towers and then is pumped to the underground cooling stations. These cooling stations are located in the technical caverns, UW25 and UW85. The demineralised water is cooled by the primary water loop via a set of heat exchangers. Once cooled, the demineralised water is sent to respective injection tunnel via supply and return pipelines in a secondary closed cooling circuit. This circuit is equipped with all the necessary control and regulating devices.

The main parameters characterising the secondary demineralised water system are as follows:

Inlet design temperature	27ºC (tolerance ±1 ºC)
Set point	26ºC
Design pressure (p)	16 bar
Δp available	6 bar
Conductivity	<0.5 μS/cm
ΔT inlet / outlet	15 K

The water cooled cables are supplied from the same pipeline as the magnets.

23.1.2 Mechanical Characteristics

The pipes used in the construction of the secondary circuits, together with all other pieces that come in contact with the water, are made of stainless steel. Compensators are installed in the supply and return pipelines in order to guarantee the appropriate contraction in case of a cool down without creating unacceptable stress on the pipes and supports. The dimensioning of the pipeline allows a margin of 15 % for any future power increase.

23.1.3 Cooling power requirements

The cooling power requirements have been defined by the users and are grouped in Tab. 23.1. These requirements served as the baseline for the hydraulic calculation of the circuits.

Table 23.1: Cooling power per injection tunnel

Circuit	Cooling Power (kW)
TI 2 (not including downstream TED)	1702
TI 2 TED (UJ22 side)	215
Water cooled cables	166
TOTAL TI 2	**2083**
TI 8 (not including downstream TED)	2967
TI 2 TED (UJ82 side)	215
Water cooled cables	136
TOTAL TI 8*	**3318**

* Some of the water cooled cables for the TI 8 tunnel are supplied from the cooling station in building BA4 of the SPS.

23.2 TUNNEL VENTILATION

The LHC main tunnel is divided in eight independent volumes, called "sectors" which are treated separately [3]. Two air handling units provide an air supply at each even point of a sector and two extraction units extract the air at the odd point of the corresponding sector. See Fig. 23.1 and Fig. 23.2.

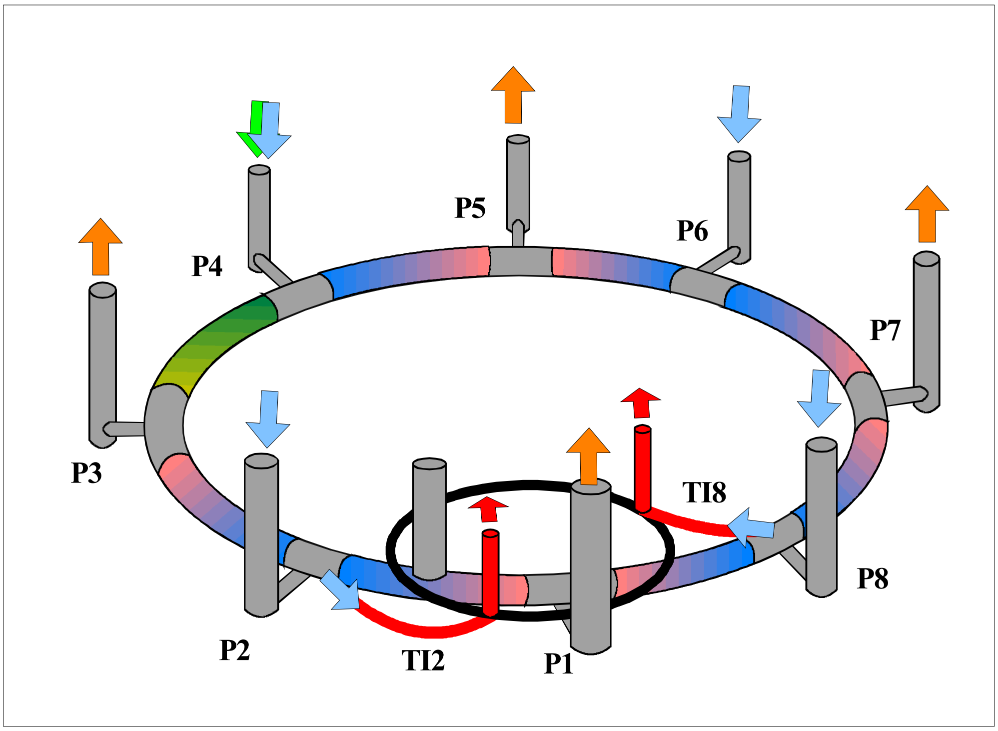

Figure 23.1: Schematic layout of the air-flows in the LHC tunnel.

The TI 2 and TI 8 injection tunnels will be in operation only during the period when beam transfer from the SPS to the LHC is taking place. The magnetic elements of the lines are pulsed following the SP supercycle for LHC filling.

A fraction of the air flow available in sectors 1-2 and 1-8 is deviated to the respective injection tunnel via dedicated extraction units. For TI 2 an extraction plant is located in SUI2 at the upstream end of the tunnel. This plant consists of two extraction units, one for normal extraction (with filters) and a second for emergency and cold smoke extraction. The same principle applies for TI 8, where the extraction plant is located in building SUI8.

In the design of the air handling installations, one of the most important aspects is the heat load which the air system must handle. This head load is the residual from many sources which cannot be evacuated in any other way. However, the air handling system must also provide many other functions including:

- Supply fresh air for people during access into the transfer tunnels
- Provide heating and ventilation during access and operation
- Provide the means to de-stratify the air and maintain a suitable temperature at the surface of the equipment
- Prevent condensation by dehumidification
- Permit cold smoke extraction (temperature $< 100°C$)
- Purge the air of the tunnel before access
- Filter the exhaust air
- Supply sound attenuation of the exhaust air

In each injection tunnel, the ventilation system will run in one of four operating modes, as shown in Tab. 23.2. In addition, Tab. 23.3 and Tab. 23.4 show the heat dissipation in the air in the injection tunnels and the resulting tunnel conditions.

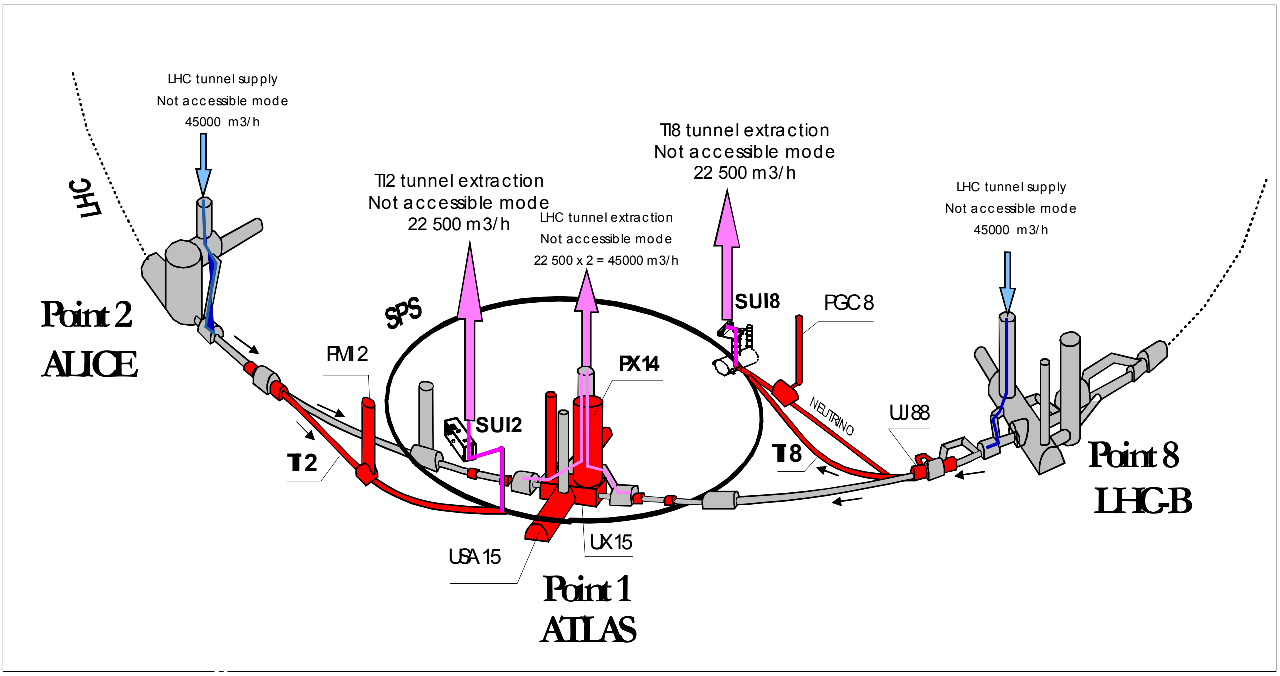

Figure 23.2: Schematic layout of the air-flows in the TI 2 and TI 8 injection tunnels.

Table 23.2: Air flow rate in each injection tunnel for different modes of operation

Injection Tunnel	Reduced consumption mode [m^3/h]	Accessible mode [m^3/h]	Not Accessible mode [m^3/h]	Emergency mode [m^3/h]
TI 2	7 500	9 000	22 500	45 000
TI 8	7 500	9 000	22 500	45 000

Table 23.3: Sources of heat dissipation into the air of the injection tunnels

Injection Tunnel	Cables [kW]	Water pipes [kW]	MBI (Dipoles) [kW]	MQI (Quads) [kW]	B340 (Dipoles) [kW]	B280 (Dipoles) [kW]	BI and Lighting [kW]	Total [kW]
TI2	200	20	127	20	35	0	11	**413**
TI8	190	20	267	20	13	5	11	**526**

Table 23.4: Injection tunnels conditions

Air supplied at the entrance:		***Exhaust air:***	
Dry bulb temperature:	20 ± 2 °C	Dry bulb temperature:	> 45°C
Dew point:	$\leq$ 11°C	Dew point:	$\leq$ 12°C

It should be noted that calculations suggest that the available air flow will not cover the heat dissipation shown in Tab. 23.3, for continuous operation. To allow this, additional local water cooled systems would have to be installed. The operating period of the injection will therefore be limited as the temperature in the tunnel will slowly rise to reach the maximum acceptable temperature for the installed equipment.

23.3 ELECTRICAL DISTRIBUTION

Electrical power for the transfer tunnels is distributed from both the LHC side and the SPS side [1,2]. For the injection tunnel TI 2, buildings LHC SR2, SPS BA6 and SPS BA7 are used to house the power converters and the medium and low voltage (MV/LV) switchboards. Galleries and ducts facilitate cabling between power transformers and converters. For TI 8, buildings LHC SR8 and SPS BA4 are used.

In each case the main dipole chain, consisting of MBI magnets, will be powered by water-cooled cables whilst rest of the magnets will be powered by conventional copper and aluminium cables**.**

23.3.1 Recuperation

In cases where the LEP installation met current safety and technical standards and when it was financially justifiable, infrastructure and equipment has been recuperated from LEP for re-use in the LHC transfer line installations.

23.3.2 Configuration

The main focus of the study of the electrical general services for the TI 2 and TI 8 was on the large voltage drops in cables as a result of the long lengths of the injection tunnels. In the past when LEP was built, alcoves were made at 1450 meter intervals of the 27 km ring to house transformers and switchboards. From these locations, electrical power was distributed for the general services. This avoided the voltage drops coming from very long cable lengths.

The cabling lengths of TI 2 and TI 8 are considerably longer: each is approximately 3 km. There is no provision for alcoves in either line. For TI 2, the ideal location of the transformer is at the top of the PMI2 shaft, outside the SMI2 building. This is approximately at the centre of the TI 2 tunnel length. For TI 8, it has been decided to install a power transformer and a switchboard in the TJ8 cavern at the SPS end of the tunnel and one in TE80 at the LHC side. Larger cable sizes have had to be used in order to keep voltage drops on cables to acceptable levels.

For TI 8, in order to make space for the new cables, disused power and control cables from the false floor of BA4, from the PAP4 shaft, from the ECA4 barracks and from the ECX4 lower cavern have been removed. A transformer pit and the connecting galleries behind BA4 have been constructed and the BA4 floor prepared to receive the steel flooring for the power converters. During the SPS shut-down 2002-2003, BB4, PAP4, ECA4 barracks, ECA4 cavern, TA40 access tunnel and TT40 machine gallery were equipped with most of the cable trays to carry machine and electrical general services cabling into TI 8. During 2004 the final cabling campaigns have been made to prepare for commissioning of the installed elements.

For TI 2 the old power and control cables in the false floor of BA7 have been removed to make way for the new cables. In addition, the floor of BA7 has been prepared to receive the steel flooring for the power converters. The cabling campaign for TI 8 began during the 2003-2004 shutdown.

23.3.3 Power Balance

The main dipole circuit is the major constituent of the power load for the injection tunnels. An analysis has been made in order to compare the reserve power capacity on the existing SPS pulsed power network, against the new load that will be added by the transfer lines TI 2 and TI 8 on the SPS side. This pulsed power network already passes through each of the BA buildings. The associated compensators for the 18 kV SPS pulsed loop are the main compensator at Prevessin (BEQ1) together with an auxiliary compensator at BB3.

The total load for TI 2, fed from BA6 & BA7, is 16.15 MVA whilst the total load for TI 8 is fed from BA4 and amounts to 30 MVA. For TI 2 the combination of BEQ1 and the auxiliary compensator BB3 is sufficient for the additional load. However, for TI 8, adding the load to the existing SPS pulsed loop would overload the loop. As a result it has been necessary to run an additional 18 kV pulsed link from the BE substation at Prevessin to BA4 for TI8. The associated compensator for the new 18 kV link is the new Static Var Compensator (BEQ2), installed on the Prevessin site.

A redistribution of the pulsed load for the SPS pulsed loop has been carefully studied and is being implemented.

On the LHC side the power situation is much simpler since there is ample power available on the network on both sites. The total load for point 2 will be 7.4 MVA (for TI 2). At this point there are two 38 MVA transformers connected in parallel. At point 8 of the LHC, TI 8 will require 5.8 MVA. A single transformer with a rating of 38 MVA is installed at this point. The existing LHC compensators have sufficient power ratings of 50 Mvar (Point 2) and 25 Mvar (Point 8).

23.3.4 Cable Dimensioning, Voltage Drop and Heat Dissipation

For each magnet circuit the voltage drop has been calculated and a cable size chosen in such a way as to not to exceed the permitted voltage drop. During the process of determining cable sizes, consideration was also given to the available space on cable trays, heat dissipation to air by the power cables and the cost. Corrector cables were carefully selected to keep the voltage drop to an acceptable level and may not necessarily have a uniform cross section for each corrector circuit.

23.4 POWER RAIL

In addition to eventually carrying the one of the beams from the SPS to LHC, the tunnel TI 2 will be used as the main route for the installation of all LHC cryogenic and the majority of warm magnets. The largest objects, the main LHC dipoles on their train weigh up to 40 tonnes. As a result powerful underground transport vehicles have been purchased. Since internal combustion engines are forbidden in the underground areas of the LHC for safety reasons, the transport vehicles are equipped with electric motors. The rated power of these motors is 380V/100A.

All existing LEP tunnels are equipped with the old monorail which has sliding contact power conductors with a rated power of 100A. These can easily be reused for the LHC transport vehicle power feed.

Because of the length of TI 2 and TI 8, battery power cannot be used for transport in these tunnels. Batteries having sufficient stored power would have a weight of up to 2 tonnes. Such batteries, moving in such a restricted tunnel would constitute a major safety hazard (acid emissions etc...). As a result is was decided to install a power feed rail in both the TI 2 and TI 8 injection tunnels. This rail is equivalent to LHC main tunnel rail, but has reduced dimensions because of the smaller space available.

At the time of writing, the installation of 6876 m of power rail has been completed and the tests are in progress.

23.5 MONITORING

The monitoring and operation of the general services for the transfer lines forms part of the general monitoring done for CERN and the LHC [3]. It concerns the following systems: electrical distribution, cooling and ventilation, access safety systems as well as the evacuation system.

The operation and monitoring of the general services will be based on both a 24 hour, 365 days shift service provided by the Technical Control Room (TCR) and on specialised equipment groups for each of the technical domains.

Dedicated computing support provides a technical infrastructure monitoring system (TIM) to the TCR. The TIM integrates and homogenises the domain specific monitoring and control systems deployed by the equipment groups.

Once the equipment is installed, faults and breakdowns will be immediately visible in the TCR, from where an impact and cause analysis is carried out. Procedures are established to ensure reliable situation assessment and fast, well directed repair interventions.

REFERENCES

[1] S. Akhtar, J. Kühnl-Kinel, "*ST/EL and ST/CV services for TI 2 & TI 8 LHC Injection Tunnels*", ST-Note-2002-019, 5th ST Workshop, Echenevex, France, 28-30 January 2002.

[2] S. Akhtar, "*Powering the Transfer Lines TI 2 and TI 8*", ST-Note-2001-019, 4th ST Workshop Chamonix, France, 30 January - 2 February 2001.

[3] LHC Design Report - Volume II (LHC Infrastructure and General Services), 2003