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NEW WORKING CONDITIONS FOR THE SPS FROM 2000

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Abstract

After the long shutdown (December 2000 to May 2001), the SPS complex will work with the main water-cooling loop in closed circuit. This will affect the working conditions because of the higher temperature of the supplied water (24 °C, i.e. 15 K higher) and therefore of the air in the tunnel. The cooling installations will consequently be upgraded or replaced to meet the new needs, and several new chilled-water stations will be installed to supply the present users. The author will thoroughly explain the main aspects of all these modifications and report the results of the preliminary tests carried out in September 1996. Finally, an overview of the global costs (operational and linked to the project) will be given, taking into account the different consumption of water, electricity and the effects on the magnet components.

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1 INTRODUCTION

The cooling and ventilation installations for the SPS complex will be modified in the 'long' shutdown from December 2000 to May 2001 because of the closing of the main primary cooling loop of the accelerator. The temperature of the water in the primary circuit will rise to 24 °C (15 K higher than the present conditions) which will cause a higher working temperature of the magnets and of all the components of the machine. The air temperature in the tunnel will therefore be higher since the thermal balance will bring the average temperature up to 32.5 °C.

In order to meet these new conditions, a different configuration of all the cooling and ventilation plants will be required: The detail of the interventions is reported in Sections 2 and 3 of this paper. In September 1996 some tests were performed to check the feasibility of the temperature rise and, as the results were completely satisfactory, no major intervention on the accelerator is foreseen. A dedicated cooling circuit will be installed for the very small amount of equipment that cannot run with a higher temperature.

As the main working parameters will change, even the operational costs will be modified: The water consumption is reduced, a different power is required for the tunnel air-handling units and the electrical needs for magnets and cavities will be higher due to a higher resistivity. The overall breakdown of the costs is reported in Section 5.

2 COOLING INSTALLATIONS

2.1 Cooling of the SPS accelerator

The closing of the main cooling loop will cause, as already mentioned, the rise of the cooling water temperature in the primary circuit up to 24 °C and therefore an increase in the temperature of all components of the machine. The temperature of the secondary circuit is kept constant at a preset value, and the possible variations are avoided by opening the regulation valves on the primary circuit (raw water) of each heat exchanger and therefore increasing the flow rate.

The SPS complex can be modelled as a single heat exchanger with a total surface and a global thermal exchange coefficient [1]; the formula that gives the exchanged power for a Plate Heat Exchanger (PHE) is

$$Q = U \times A \times LMTD \qquad (1)$$

where

- Q = cooling power for the PHE,
- U = heat transfer coefficient,
- A = surface,
- $LMTD$ is the logarithmic mean temperature difference = $\Delta\vartheta_1 - \Delta\vartheta_2 / ln(\Delta\vartheta_1 / \Delta\vartheta_2)$, where $\Delta\vartheta$ = water temperature difference between the inlet and the outlet in the PHE.

This model shows that an increase in the set-point values of the equipment and the increase of the temperatures in the demineralized-water circuit will demand minor consumption of primary water. The future parameters for the cooling installations are reported in Table 1.

Table 1: Main parameters for the SPS complex in the future configuration.

Total power [MW]	55
Inlet temperature from the lake [°C]	10
Inlet temperature in the primary circuit [°C]	24
Lower temperature of the demineralized water [°C]	25
Maximum temperature variation in the secondary circuit $\Delta\vartheta$ [K]	15
Nominal primary-circuit flow rate [l/s]	1000
Global demineralized-water flow rate [l/s]	950

1.2 Plate heat exchangers

The PHEs will be replaced because of new thermal exchange parameters. The main characteristics of the PHEs are reported in Table 2.

Table 2: Main characteristics of the PHEs in the future configuration

Total number		17
Pressure drop [kPa]		15–60
Demineralized water – secondary circ.:	Inlet temp. [°C]	40
	Outlet temp.[°C]	25
Raw water – primary circuit:	Inlet temp. [°C]	24
	Outlet temp.[°C]	39

Referring to Eq. (1), since the cooling powers needed are constant for each PHE, the different value of *LMTD* must be compensated for by a different value of $U \times A$. In the present situation the *LMTD* value for the main magnet circuit in BA3 (311) is 4.4 K; in the future it will be 1 K; it is therefore necessary to install a new PHE with a $U \times A$ value more than four times greater.

1.3 Cooling towers

The closing of the main SPS cooling loop and of other minor circuits means that all the thermal charges will be cooled by the existing cooling towers located in LEP Point 1. An upgrade of the cooling capacity is needed by modifying part of the equipment, namely the packing (providing a higher exchange surface) and the motors of the fans (providing a higher air flow through each cell). At the same moment all the material containing asbestos will be replaced.

Table 3 presents a list of the main parameters, showing the difference between the present and the future situation.

Table 3: Main parameters for the SPS cooling towers

	Nominal power [MW]	Water temperature inlet [°C]	Water temperature outlet [°C]	Flow rate [m^3/h]	Fan motor power [kW]
Present situation	40	37	24	3600	55
Future situation	70	44.7	24	3600	110

The increase of cooling power will be quite high and therefore no spare cell will be available; in case of problems the spare will be represented by some cold water coming from the lake at a mean temperature of 10 °C.

The same modification (with some slight differences and different parameters) will be made to the Prévessin cooling towers as well; they will be connected to all the circuits in the North Area and will not directly affect the SPS complex.

1.4 The control system

The control system will be modified by installing at a local level a single PLC and one industrial PC; the communication between them will be made via a Profibus network using a Wizcon software. Every control system in each BA will be connected at a higher level to the Ethernet TCP-IP network from where the TCR will receive the necessary information. A user's access will be provided by a web server for supervision and data analysis. Other servers will be used as data archive to store the configuration files or the real-time data.

At present no local supervision is possible, while in the future an effective monitoring and control system will be available.

3 VENTILATION INSTALLATIONS

3.1 SPS tunnel

The ventilation system of the tunnel is used mainly to ensure ventilation, to keep the temperatures and dew point in the tunnel below certain pre-set values and to provide a sufficient air flow in case of smoke removal (in this last case no control on humidity and temperature is foreseen). Some parameters will be modified from the existing configuration in order to give better performance and to reduce the installation and operational costs.

The air flow has been increased to 55 000 m^3/h maximum in all three units (at present the supply in BA4 is about 45 000 m^3/h): This will give a better balance of the air distribution between the supply and the extraction. Moreover, in the future configuration the dry bulb temperature will be set to 20°C and the maximum dew point will be 15°C (at present respectively 25 and 12 °C). The temperature of the supplied air is lowered to 20 °C (at present 25 °C). In this way the cooling coil will need 430 kW (instead of 600 kW) and the post heating unit will demand 230 kW (before 310 kW).

The equilibrium air temperature in the tunnel can be calculated with the following equation:

$$t_T = t_S + \Delta\vartheta / 2 . \qquad (2)$$

The set-point temperature will be t_s = 25 °C and the temperature variation $\Delta\theta$ = 15 K (see Table 1). This will give a temperature in the tunnel t_T = 32.5 °C, compared to the existing 27.5 °C.

These modifications will affect neither the comfort in the tunnel nor the proper functioning of the accelerator. As the task of the ventilation system is to maintain dry conditions to avoid condensation and corrosion, no cooling purpose is required of the air in the tunnel.

3.2 Surface buildings

At present, the water coming from the lake (10 °C) is used for the air conditioning of the surface buildings; the computer control rooms are conditioned by a dedicated installation. After the long shutdown the necessary chilled water will be provided by one chilled-water production plant (6–12 °C) per BA. Depending on the power needed the chiller will be water (up to 700 kW) or air cooled: In the first case the water will be taken from the SPS main cooling loop. The higher cost of the air-cooled chillers is partly compensated for by the minor cooling capacity needed in the cooling towers.

The computer control rooms will be conditioned with a free cooling system: during winter time the air is taken from the outside and no chilled water will be needed; during summertime the connection to the centralized chilled-water plant will provide the necessary cooling capacity. This solution will avoid running a big installation (up to 700 kW in some cases) for a very small need (around 20 kW maximum) during the shutdown period and minimize the operational costs.

The chilled-water circuit will be connected to the mixed-water one used to cool the septum magnets, in order to guarantee a spare solution in case of problems.

4 TESTS

Before the launch of the project some tests have been performed in order to check the feasibility of the intervention and the possible modifications to foresee.

In the first set of tests held on 26 August 1996, the set point was increased from 20 to 27 °C for 30 hours. The main effects were the decrease of the resistivity of the demineralized water in all the SPS and in particular in the septa magnet from 12 MΩ/cm to 8 MΩ/cm at the outlet of the exchange cartridge, and the heating of the quadrupoles in sextant 2 (mainly because of a malfunctioning control cable and an electronic board). The vacuum on the TWC4 increased by a factor of 1000.

The second series of tests was held from 13 to 26 September 1996 in different steps.

- 13–16 September, increase of the set point from 20 to 22.5 °C except for the following circuits: Septa BA2, BA6 and the power supply BA5, SWC BA3.
- 16–26 September, increase of the set point from 22.5 to 25 °C.
- 26 September, no beam, increase of the temperature from 25 to 30 °C in three steps.

No particular problem occurred in all this period. All the tunings with a proton beam have been tested (Q, radiofrequency, chromaticity) and very few differences were measured. The check on the SPS power converters equipment showed that the equilibrium was reached after 40 minutes maximum in the filter chokes at 39.5 °C, and in the thyristor stacks at 31°C with an input water temperature at 28 °C [2].

In the RF equipment [3], only the 100 MHz Travelling Wave Cavities are concerned by the higher temperature of the water that will cause a different transition frequency (due to the slight modification of the geometry of the cavity) with a consequent phase mismatch. It will be better therefore to foresee a separate cooling circuit with the same water temperature as at present. The same modification on the 200 MHz Standing Wave Cavities will not cause any mismatch since the range tuning is sufficient to compensate for the variation of geometry.

The septum magnets will be cooled with mixed water (13 °C inlet, 19 °C outlet) in the primary circuit since the lower resistivity in the cooling water at 25 °C cannot be accepted.

The overall result of the test was therefore positive, showing that no particular intervention has to be done to the SPS accelerator.

5 COSTS

The global costs of the project have been reduced to the minimum by modifying some of the current configuration and parameters, such as the air conditions in the tunnel, the use of air-cooled chillers and the use of some fresh water from the lake as a spare solution for the cooling towers. This gave fewer constraints in the design phase and allowed a smaller size of several components. At the same time particular attention has been given to the operational cost once the SPS is running in a closed circuit, and significant improvement can be foreseen.

Obviously the main gain will be in the water consumption that will be reduced from 1000 to 35 l/s in standard conditions for a global 30% reduction in consumption for all of CERN. The estimated saving is about 360 kCHF per year (for 6000 working hours and a water consumption cost of 0.05 CHF/m^3). The waste water discharged into the river will be reduced as well, representing an important advantage from the environmental point of view. The overall energy consumption in CV installations will be higher because of the need to evacuate a higher thermal charge and because of the new chilled-water circuits in the BA (installed electrical power about 2500 kW). The cooling towers will demand 50% more, while the AHUs will reduce their power by around 25%. Considering a cost of 0.047 CHF/kWh, the operational cost increase can be estimated at 160 kCHF per year.

Concerning the accelerator, the energy consumption will rise according to the higher resistivity of its components: For the water-cooled cables and magnets the resistivity will rise about 6% and the related energy consumption will be directly affected. The air-cooled cables (representing about 20% of the global resistivity of the circuit) will increase their consumption by about 0.4% per degree, therefore they will need about 1% more consumption. Given the same unit costs as above the overall cost increase for the machine can be estimated at around 370 kCHF per year.

In Table 4 a list of the main costs linked to the project is reported; for a more detailed breakdown of the global costs please refer to Refs. [4] and [5].

Table 4: Cost breakdown of the project

	COST [kCHF]
Network and pumping-station restructuring (CERN activities)	773
Works on Prévessin site	2 407
Works on LEP	2 325
Works on SPS: total	11 749
PHE	2 300
Valves and piping	549
Cooling towers	3 999
BA air conditioning	3 086
Tunnel AHU	825
Controls	990
TOTAL	**17 254**

Other savings can be made by the other activities linked to the project, mainly concerning the collaboration with the Service Industriels de Genève (SIG) for the operation and the refurbishment of the distribution network and the pumping station inside and outside CERN.

6 CONCLUSIONS

According to all the topics mentioned in this note the main goals of the project are the rationalization and simplification of some of the CV installations in the SPS complex and the minor operational cost during the running of the accelerator. The accelerator was built in 1976 and several modifications have been made or are foreseen in the near future; the new configuration of the cooling and ventilation will be more adapted to the future needs.

It is important to note how the modifications will concern ST/CV installations, not demanding additional hardware works to the SPS accelerator and its equipment but a general tuning of the parameters to the new values. Where the new conditions would have demanded important modifications on other equipment (as for the radio-frequency), the present parameters will be maintained.

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