Cryogenic Issues for LEP in 2000

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Abstract

During the shutdown 1998/1999 the installed cryogenic dynamic refrigeration capacity has been increased from 6.7kW to more than 12kW per cryoplant. The upgrade achievements and limitations are presented. The operation statistics are analysed with a particular emphasis on the turbine filter clogging phenomena. Plans and actions taken during the shutdown 1999/2000 to reduce the frequency of the turbine "de-icing" will also be presented. Finally, the cryoplants performances during 1999 and expectations for the forthcoming high energy run will be analysed.

1 CRYOGENICS UPGRADE

In order to allow LEP operation at high beam energies all LEP2 cryoplants were upgraded during shut down 98-99. The available refrigeration capacity was increased from 6.7 kW to 12.3 kW at 4.5K using additional helium mass flow and modifying the cold box. This new mass flow required the use of the redundancy compressors installed previously, the addition of one extra compressor per cryoplant and the adaptation of the oil/helium separation and cooling system. The cold box modifications required to install a complete new turbines set in all the cryoplants.

This work was done in an extremely tight time schedule and the start up was carried out without any major problem within the LEP deadlines. Nevertheless, first measurements after restarting the plants showed up to main problems at IP4 and IP6 cryoplants.

- A temporary power reduction of ~1.2kW due to high vibrations in some compressors. The problem was solved during June'99 by local fixing and grouting of the skid beams on the concrete foundation blocks.
- A lack of ~2.4kW of cooling capacity due to a wrong design of the turbines. A new turbine set was installed at IP6 cryoplant just after LEP stopped and the design value of 15.7kW was achieved; the second set for the IP4 cryoplant was installed beginning 2000.

In spite of the missing power, the achieved new capacity allowed LEP to run at 101 GeV beam energy (7MV/m) and 6mA total beam current as shown in Table 1.

Table 1: Power balance after 98-99 Upgrade

	IP2	**IP4**	**IP6**	**IP8**
Available	14.0kW	10.3kW	10.7kW	13.6kW
Load	6.1kW	8.7kW	9.4kW	10.5kW
Margin	7.9kW	1.6kW	1.3kW	3.1kW

2 1999 OPERATION PERFORMANCES

During 98/99 winter shut down, 4 new SC modules were installed (2 at IP4 and 2 at IP8).

During 1999, the youth of the new installations and the utility failures has resulted in 166 hours of beam time lost. Almost 60% of this time was lost due to direct cryogenic failures (see table 2), with special incidence of the oil pump leak at IP4. In general, the cryogenics impact on LEP has increased by only 1% over 1998 statistics [1].

Table 2: LEP2 cryogenics statistics in 1999

	Cryo	Utilities
IP2	11:39	23:25
IP4	64:26	12:11
IP6	0:00	58:10
IP8	27:25	26:31
Global	103:30	120:25
LEP impact	95:51	70:21
LEP run time	4512	4512
%	2.12	1.56
Total % 1999	3.68	
Total % 1998	2.68	

3 CRYO DE-ICING

The increase of flow through the cold box due to the upgrade strongly increased the turbines clogging phenomena during 1999, mainly at IP4 and IP6 cryoplants, resulting in 146 hours without cryogenics availability for RF. Coordination with SL/OP team has allowed to profit from this time for MD or other interventions in the machine.

3.1 Turbines clogging phenomena

Based on investigation done in 1998 and 1999 it appears that the reduction in turbine flow, so the progressive reduction of the dynamic power available for

RF and beam loads, is due to the clogging of the 1st and 2nd turbine filters. Since the first is due to water contamination and it needs periodic de-icing (cleaning of the filter) because of the continuously increasing ΔP over the filter, the second is probably due to CO_2 contamination and does not need de-icing as it stabilizes within a safety margin in two days (figure 1).

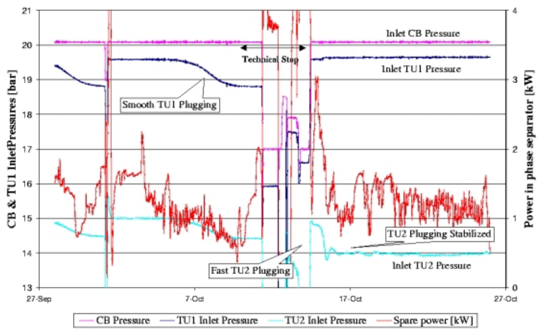


Figure 1: Typical turbines clogging

3.2 Turbine 1 clogging: water contamination

The main water contamination sources are:

- By open circuits

Maintenance during winter shut down requires to open circuits (compressors maintenance, replacement of turbines, modules maintenance in SM18, etc…) consequently, an accurate conditioning is needed before starting up. In order to minimize this effect the conditioning procedures have been improved.

- By water accumulation over the past years

A fraction of the water impurities contained in the helium is frozen in the first heat exchanger of the cold box. This year a complete drying of all the circuits (turbines, high, middle and low-pressure circuits) of the cold box using warm nitrogen has been done.

- By Oil

Treated oil contains 0.5mg H_2O/kg. During 1998/1999 shutdown the total quantity of oil was replaced in each cryoplant (about 2000 l.) because of the upgrade. In 1999-2000 winter shut down a maximum of 400 l. will be added per point, which means about 0.2 l. of water.

- By Helium

The presence of ice crystals in liquid helium delivered could also be a contamination source. Considering an average quality of 5ppm of water, a He delivery of 20000Nm3 would represent ~0.1 l. of water contamination. A filter will be installed in the filling transfer line to be used for future helium deliveries.

3.3 Turbine 2 clogging: CO_2 contamination?

Measurements at the end of Run'99 showed up CO_2 traces when cleaning the filter of the second turbine. Although more exhaustive measurements are required, the walls of the gaseous helium storage tanks and the absorber's active charcoal could be the source of contamination. A complete mapping of the helium quality was made for all tanks and a detailed study will be done when restarting the cryoplants.

4 RUN'99: FROM 96GEV UP TO 101GEV

4.1 Beam influence

During 98/99 winter shut down all the antenna cables of the super-conducting cavities (except 4 modules at IP2) were replaced, which allowed to reduce beam-induced loads by a factor of two. Figure 2 represents the evolution of the remaining cryogenic power available during a typical LEP cycle in the four cryoplants. Considering this evolution as a function of the squared beam intensity, an average bunch impedance Z_b= 8 MΩ can be calculated, which represents the predicted reduction [1].

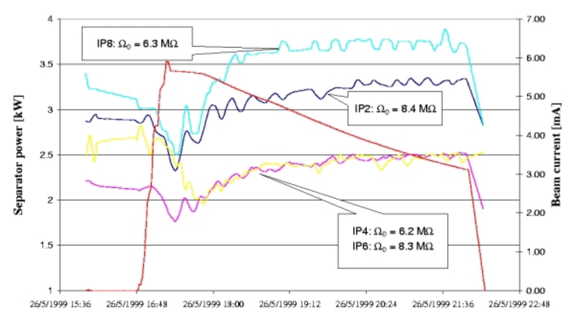


Figure 2: Cryogenic power load vs. beam at 96GeV

4.2 Q factor evolution

An important issue for high-gradient operation of the SC cavities is to determine whether the external Q factor of the cavities is degrading over a year of operation.

During 1999 the RF system has pushed its limits up to an averaged 7.27 MV/m field [4]. Several cryogenic measurements of the Q factor have been performed, predicting better values than expected for high RF voltage gradients, 2.8E-9 at 7 MV/m (figure 3).

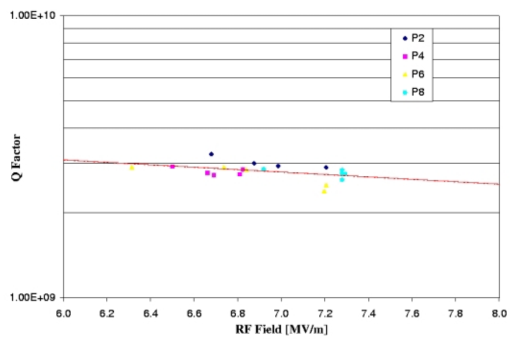
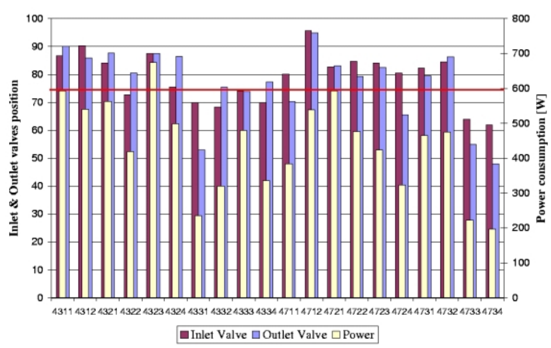


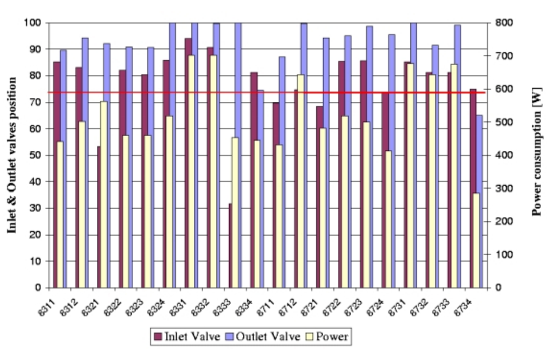
Figure 3: "cryogenic" Q factor vs. RF field evolution.

4.3 Modules capabilities

In spite of the good Q factors, running at high gradients has pushed some modules to the limit of flow capacity of their valves [1]. This limit is given by the head losses in the valves and the flexible lines connected to the modules, which have been designed for a much lower accelerating gradient than the expected now.

The effect is more important at IP4 and IP8 where the transfer lines were manufactured by a different firm than the other point.





Figures 4 & 5: Inlet & outlet valve position and cryo power consumption for IP4 and IP8 modules.

Figures 4 and 5 show the inlet and outlet valve positions vs. the power dissipated in the modules at IP4 and IP8 respectively. The maximum acceptable flow, which corresponds to 600 W per module as stated in [2] is, in some cases, largely exceeded.

4.4 Cryogenics up to 101 GeV

The LEP2 cryoplants have successfully followed the LEP increase of energy over the year up to 101 GeV. Periodic adjustment of modules heaters and tuning parameters to prevent waste of cryogenic power, the reduction of the beam effect and the increase of operation pressure of modules have allowed to reach the 101 GeV target.

Figure 6 shows the evolution of the reserve cryogenic power for two fills at 101 during test to analyse RF instabilities.

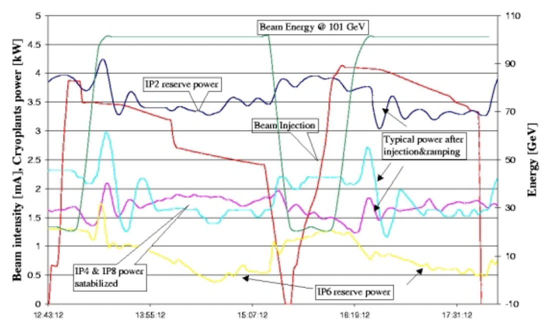


Figure 6: Cryo power evolution at 101GeV

5 FORECAST FOR 2000

5.1 De-icing

During 1999/2000 winter shut down preventive actions were carried out in order to reduce if not eliminate the filters water clogging. Exhaustive analysis and follow up of the phenomena after the start up will allow to predict the periodicity of cryo de-icings for 2000 if needed.

5.2 Energy limitations

According to measurements and performances over 1999 and the power tests with the new turbines at IP4 and IP6, the cryogenic power for the four cryoplants will be sufficient to push LEP above 101 GeV. Table 3 shows the available cryogenic power, the calculated load for 7.6MV/m and 6mA beam current and the final expected margin, which means running LEP at 103 GeV with 2 klystrons margin [4] should be possible.

Table 3: Power balance for 2000

	IP2	IP4	IP6	IP8
Available	14.0kW	12.7kW	13.2kW	13.6kW
Load	9.3kW	12.3kW	10.7kW	11.7kW
Margin	4.7kW	0.4kW	2.5kW	1.9kW

Nevertheless, these global figures do not consider the flow limitations for the module's valves mentioned before. Special attention will be required for some modules when increasing RF fields above 7.2MV/m.

6 CONCLUSIONS

In conclusion, the cryogenic system should not be in 2000 the limiting factor for running LEP above 102 GeV. According the LEP2 scenario proposed for 2000 [5], a tight coordination between RF, SL/OP and cryogenic operation teams will be necessary.

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