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First Operational Experience in Running a New 6 kW Cryoplant Cooling Superconducting Cavities in LEP at 4.5 K

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ABSTRACT

The LEP200 upgrade project under way at CERN will bring the particle energy in the 27 km long LEP electron/positron collider up to 90 GeV, thus doubling the energy of the machine. Some 200 sc cavities, working at 352 MHz, will be installed at the 4 interaction points. They are mounted in 4-cavity modules and are bath cooled by 4.5 K LHe from one cryoplant at each point. Since beginning of 1992 a 6 kW refrigerator is in operation at LEP Point 2 for cooling of the first cavity modules. During the 1992 LEP run the cryosystem with 3 modules and its controls has been considerably improved. In this paper the experience during the LEP run of 1993 concerning plant reliability, stability and interaction with RF fields is reported.

I Cryoplant description

CERN is using for its first station of sc cavities at LEP Point 2 a very efficient 7-turbine cryoplant supplied by SULZER/LINDE end 1991 [1]. It provides a total of 6 kW equivalent cooling power at 4.5 K level, which is composed of 5 kW of refrigeration at 4.5 K + 8 g/s of liquefaction flow used to cool accessories of the cavities (couplers, tuners etc.) + 3 kW below 80 K for cooling the transfer line screens.

The cryoplant consists of 3 compressors in a surface building : 2 low-pressure and 1 high-pressure screw compressors able to deliver 390 g/s of GHe at 20 bar. The compact coldbox is located in the LEP service tunnel 60 m below ground level with dimensions matched to the available space. Transfer lines with a total length of 570 m connect the coldbox to the cavities in the beam tunnels on both sides of the LEP interaction point 2. The overall power factor achieved with this plant is near 235 W electric input for 1 W at 4.5 K.

The cryoplant was commissioned and the software for the ABB control system improved during the LEP run of 1992 when three 4-cavity modules were sometimes operated with LHe and sometimes cooled with cold helium gas. During the present 1993 run of LEP, only 2 modules are installed at LEP Point 2, but the cryogenics is fully operational and running automatically with operators only on call.

II Cryogenics of the sc cavity modules for LEP

The sc cavity modules for LEP consist of four 4-cell cavities in a common vacuum tank [2,3,6]. Each cavity is surrounded by a separate LHe bath tank and all tanks are connected in parallel to a lower LHe manifold and an upper phase separator and GHe manifold.

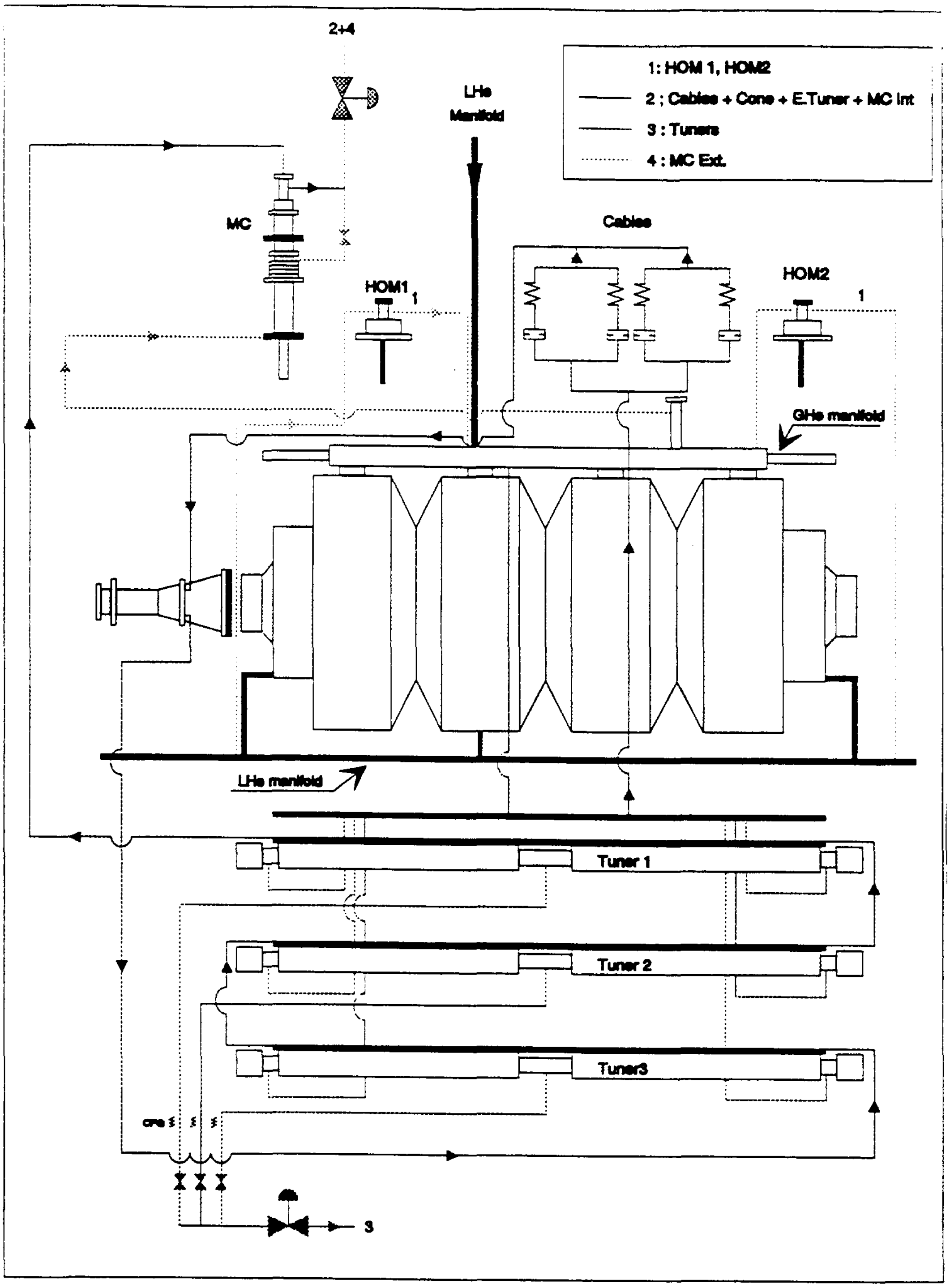

Fig 1 Cryogenics circuits of a cavity in the LEP

The LHe level in the bath is controlled by the inlet valve between supply transfer line and LHe manifold, and the bath pressure by the outlet valve between the GHe manifold and the return transfer line. Thus all modules are connected in parallel to the transfer line system and controlled independently by 2 valves each.

For efficient cooling of the HOM (High Order Mode) coupler with bypass pipes between LHe manifold and GHe manifold (see Fig. 1) a LHe level as high as possible is required, but overfilling of the cryostat must be avoided in the interest of thermodynamic efficiency of cryoplant operation. Since the tunnel is ramping at a slope of 1.4 % at LEP point 2 only the level of the "upper" cavity is a free parameter being used for the level control. In spite of the restricted gas volumes inside the modules very satisfactory stability of levels and pressures are achieved (see Fig. 2).

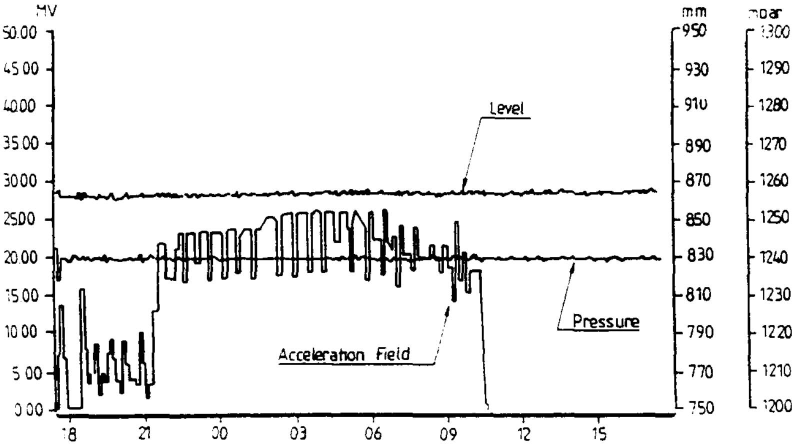

Fig. 2 : Stability of the Helium bath in a module

0.8-1.2 g/s of GHe at 4.5 K per module is taken from the manifold and used to cool heat intercepts on main couplers, tuners and beam pipe transition cones. The gas cooling circuits are chosen to make best use of gas enthalpy and simplify instrumentation and operation. 2 warm control valves per cavity can be used to modulate the gas flow in response to heat loads varying with RF (Fig 1) [5].

III Stability of cryogenics with varying heat loads from RF and beam

To achieve satisfactory stability (Fig. 3) of bath pressure (1250 $^{+}/_{-}$ 2 mbar) and level (800 $^{+}/_{-}$10 mm) in all modules with many interacting control loops in the cryoplant, changes of dynamic heat load into the LHe should be compensated as well as possible inside the modules. The RF field produces a heat load in the cavity walls which is proportional to the square of the field strength E and the inverse of the quality factor Q of the cavity.

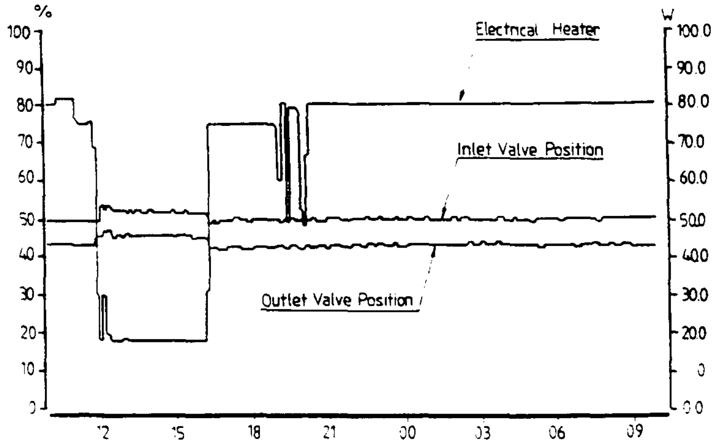

Fig. 3 : RF heat load compensation before Q value tuning versus time (hours)

This dynamic load is compensated by using electric heaters in each cavity He tank, to which at zero RF a pre-determined heat load is applied (in 50-150 W range). With an analog signal of the varying RF levels the control system is calculating the expected RF load and reducing on-line the heater power correspondingly. If the right value is chosen for the effective Q of each module, even drastic and rapid changes of the RF field have almost no influence on bath pressure, bath level and the corresponding valve positions (Fig. 3 and 4).

The fields induced by the LEP beam bunches (8 bunches each of electrons and positrons in 1993) also produce heat, which is expected to be proportional to the number of bunches and to the square of bunch charge. No reliable prediction is yet available for the spatial distribution of the induced fields.

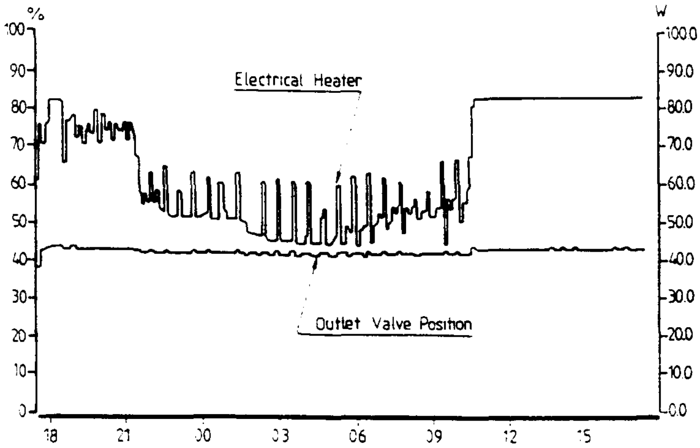

Fig 4 : Tuned RF load compensation versus time (hours)

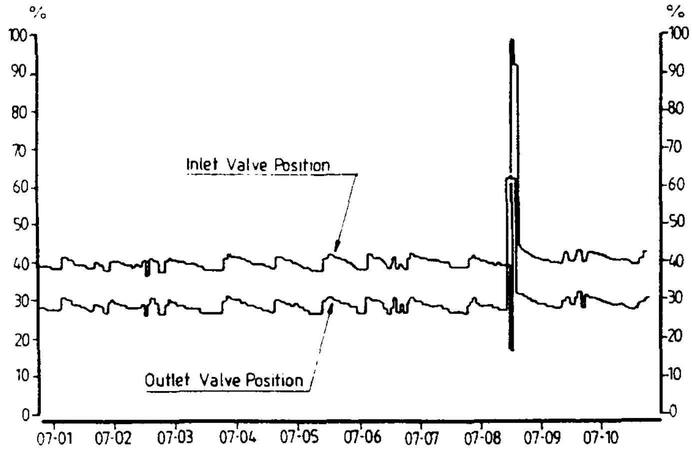

Fig 5 :Beam influence on LEP module versus time (days)

As Fig. 5 shows, the achieved stability of pressure and level control was such that the variation of the beam load during filling and the exponential decay of the currents in the mA range for both positrons and electrons became visible by the regular swing of the control valves during each beam period (10-20h). Since the position of the valves is proportional to the He flow rate through the module, they are reacting as soon as an additional heat load is induced by the beam. The peak load from beams is estimated to be close to 100 W (Fig. 6).

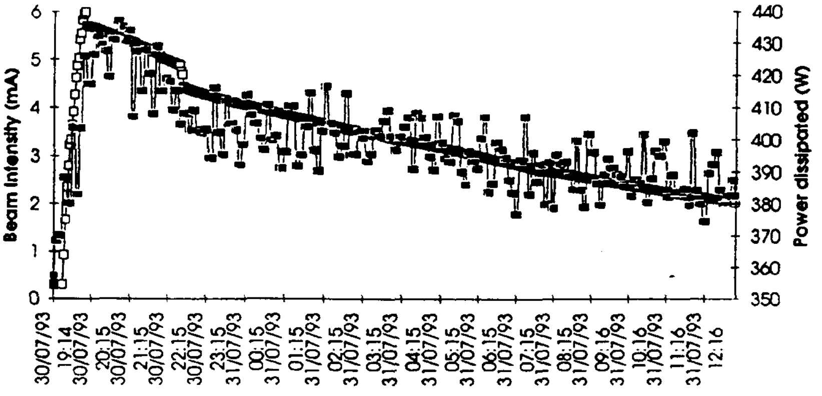

Fig 6 :Beam induced heat load.

IV Cryoplant reliability

With the installation of more and more sc cavities in LEP, the performance of the machine will depend on the full availability of all cryoplants. No redundant cryogenic equipment has been installed, but some 100% spare capacity is available for RF load beyond the 50 W per cavity, corresponding to the initial value of 5 MV/m and $Q = 3.10^9$. It is thus essential that the new LEP cryoplants can run reliably over machine periods of at least 8 months.

Experience with routine operation of the 6 kW cryoplant at LEP Point 2 during the 1993 run was very encouraging. During the first 21 weeks only 2 short programmed technical stops were made available for technical interventions. Unwanted stops occurred only exceptionally. In Fig. 6 the reasons for all accidental stops of 1993 are analysed. With the exception of one operator error, all other stops were due to problems in water or electricity supply.

Another main objective of our current work of controls optimisation is the fastest possible refilling of the modules after an accidental stop of the cryogenic system.. Considerable delays cannot be completely excluded during start-up of such big and complex machines, and each minute without helium gas flow leads to additional constraints for restart because of thermal stress in the very big heat exchangers. Fig. 7 shows the recovery delays achieved in 1993.

- Time for cool down of coldbox with modules	12 h
- Filling of cold modules, 1/2 transfer line + 2 modules	4 h
- Filling of modules with full transfer line + 8 modules	12 h estimated
- Emptying of a module with 800 l of LHe, due to static heat load	6 h

Table 1 : Typical duration of normal cool down and warm-up operation using the 6 kW plant.

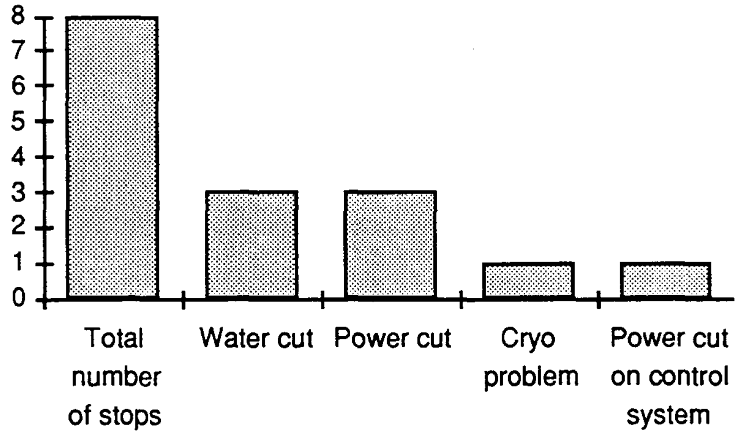

Fig 6 : Origins of the cryoplant failures in 1993.

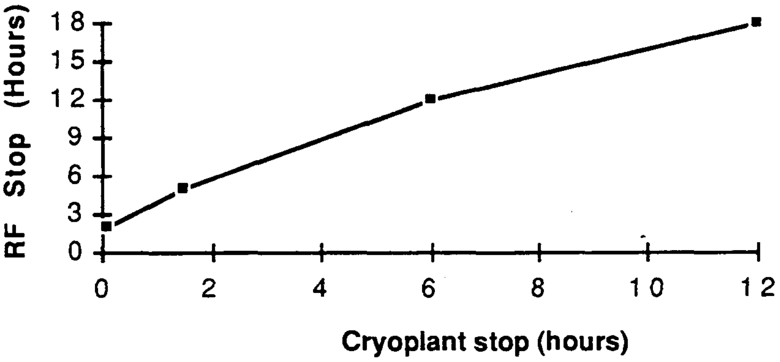

Fig 7 : Observed relation between duration of cryoplant stops and interruption of RF services