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SUPERCONDUCTING CAVITIES FOR LEP

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Abstract The upgrade of LEP to beam energies of 100 GeV will be made using superconducting RF cavities. The cavities are operated at 352 MHz, as the room temperature ones and they will keep the same RF power distribution scheme, using however only one klystron for 16 cavities instead of two klystrons. Four 4-cell cavities have been produced out of Nb sheet material. They are equipped with cryostat, power and HOM couplers, cavity tuners and controls. Each has been individually tested and they have then been assembled in a 4-cavity cryostat module. The module will be installed in a test mockup to study liquid helium supply schemes, RF power distribution and remote controls. Installation in the ring is scheduled before end 1989. Orders have been placed to industry for twenty 4-cell cavities of Nb sheet material with all the required accessories. The cryogenic system for 32 cavities of the first LEP upgrade step has been worked out. Nb sputtering of Cu cavities is being actively pursued. One 4-cell cavity is ready for installation in the ring and 4 are under production.

INTRODUCTION

During the last two years a LEP type superconducting (sc) cavity has accumulated inside the CERN SPS accelerator more than 8000 h operating hours at 4.5 K [1]. No irreversible degradation of cavity performances has been observed and no major system failures have occured. These results incited us to launch the fabrication of four more cavity-cryostat systems, two of which were produced at CERN and two at industry (LEP3,4,5,6).

RESULTS WITH THE FIRST FOUR LEP CAVITIES

A few results [2,3] obtained with the individual cavities inside their horizontal cryostats are summarized in Table I and a typical Q_0 versus E_{acc} curve is shown in fig. 1.

All cavities exceeded design fields of 5 MV/m for LEP. For three cavities, Q_0 values at 5 MV/m remained somewhat below the design value of 3×10^9. It has been shown that this is due to an insufficient shielding of the surrounding magnetic field not being perfectly homogenous. For an ideal magnetic shielding one extrapolates Q_0 (4.2 K) = 4.1×10^9 for low fields.

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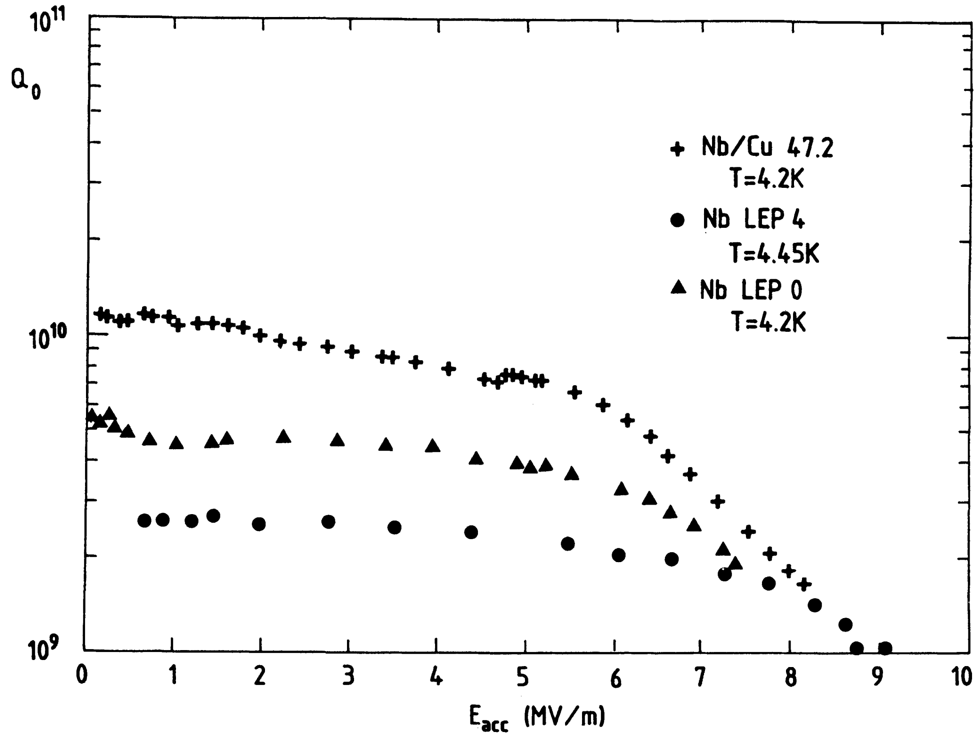

FIGURE 1 Dependence of Q factor in accelerating field E_{acc} for 350 MHz, 4-cell LEP cavities. Cavities LEP0 and LEP4 are fabricated from Nb sheet material, cavity 47.2 is a Cu cavity with a magnetron sputtered Nb layer. The reduced Q values of cavity LEP4 are due to an insufficient shielding of external magnetic fields.

TABLE I A few experimental results of the first LEP s.c. cavities

	LEP3	LEP4	LEP5	LEP6
Manufacturer	Interatom	Interatom	CERN	CERN
Residual resistance ratio of Nb	224	212	128 ÷158	128 ÷139
Maximum E_{acc} (MV/m)	5.4	8.6	9.0	5.5
Field limitation	quench	rf power	quench	quench
Low field Q_0	3×10^9	$2{,}7 \times 10^9$	–	–
Q_0 at 5 MV/m	2.2	2.2	3.3	2.0

AUXILIARY EQUIPMENT

Besides cavity development, a considerable effort has gone into the design, construction and testing of cryostats, couplers and tuners [4] which present about 50% of the total cost of the cavity system. The auxiliaries for the first four LEP cavities have already been fabricated and tested at CERN. They have undergone by now a long-term test with cavity LEP2 in the CERN SPS [1].

As a compromise between a reasonable filling factor (~ 60%) and the transport possibilities inside LEP a basic unit containing 4 s.c. cavities inside a common insulation vacuum with a total length of 11 m was chosen. These units are assembled under clean conditions in a mounting hall, and then transported to their final location inside the machine tunnel.

Cryogenic tests on individual cavity-cryostat units equipped with main and hom couplers, with frequency tuners and beam tube transitions to 300 K have been performed. At operating liquid helium level and with 0,2 g/s of cold He gas flow through the various heat exchangers, tuners and radiation shield, static losses of less than 17 W have been measured.

Safety tests [5] simulating the most dangerous vacuum failure, i.e. a break of the ceramic window of the main coupler have been performed and the adequacy of the chosen safety valves and rupture disks for the He vessel (200 ℓ LHe/cavity) has been demonstrated.

PREPARATION OF THE FIRST SUPERCONDUCTING CAVITY OPERATION IN LEP

It is foreseen to install a unit of four s.c. cavities in LEP, as soon as possible after its start-up. The assembly [3] of the four cavities has been finished and has allowed to appreciate fully the excellent accessibility conditions offered by the cryostat design. Mounting and alignment of individual cavities is easy and not hampered by mechanical overconstraints or excessive mechanical tolerances.

After assembly the four cavity units (fig. 2) will be installed at the test mock-up previously used for a basic module of 16 Cu cavities. RF tests will be performed by using the existing klystron-circulator-waveguide system and large parts of the associated control and regulation units. Liquid helium at 4.5 K is

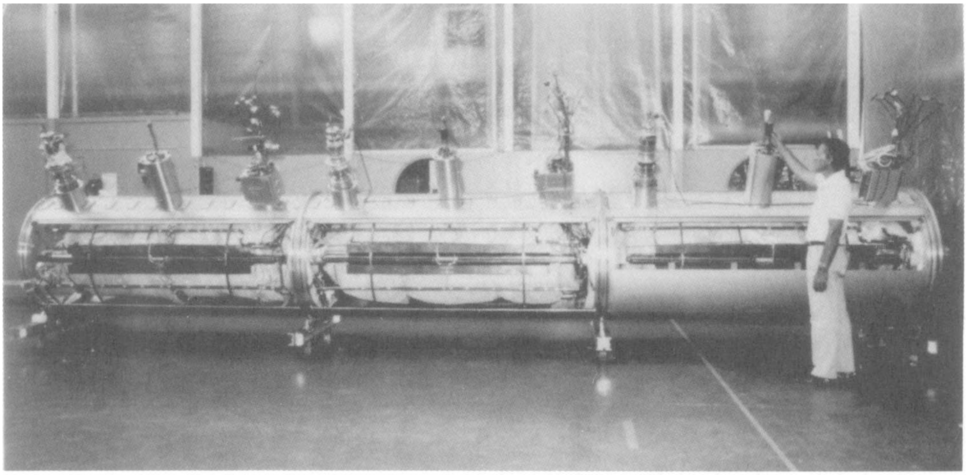

FIGURE 2 Assembly of three 4-cell LEP cavities. This unit will be completed by a fourth cavity.

supplied by a 450 W refrigerator. Cavities can be cooled either independently or simultaneously by a He distribution line similar to the one already installed in LEP for the first s.c. cavities. First tests on a two-cavity unit have shown that cooling by "overflow" of LHe from one cryostat to the next is possible. This would greatly simplify the LHe distribution system and reduce the number of cold valves.

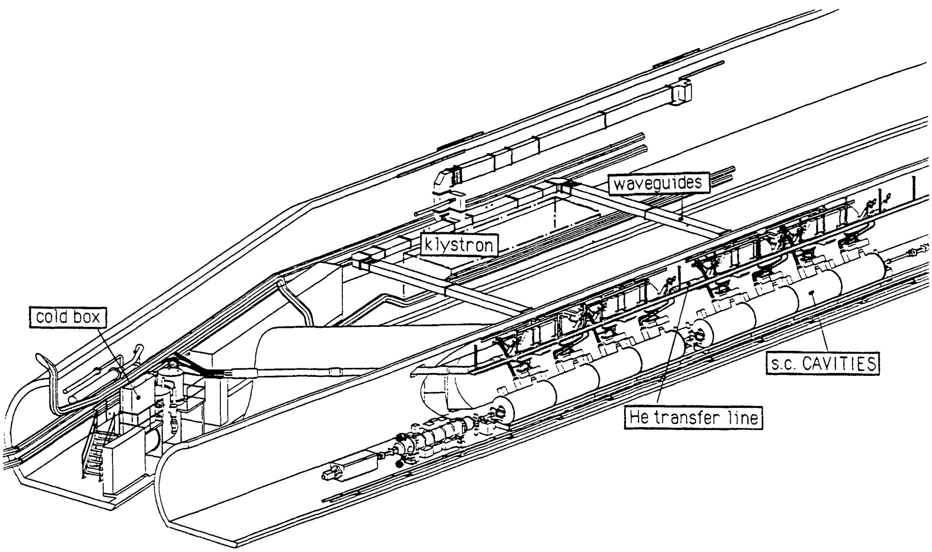

FIGURE 3 Layout of the first four s.c. cavities inside LEP with cryogenics, RF waveguides and klystron system.

For the first operation in LEP a RF system with one 1 MW klystron similar to the one used for the Cu cavities has been prepared. He transfer and distribution lines are already installed as well as a 1 kW refrigerator whose cold box is located inside the klystron tunnel (fig. 3). The control systems for RF, cryogenics and vacuum are operational. It will therefore be possible to install the first four s.c. cavities unit during a relativity short shutdown period following the initial start-up period of LEP.

With four cavities and with a gradient of 5 MV/m a total acceleration voltage of 34 MV is obtained. This should give an interesting possibility for storing and accelerating LEP beams up to ~ 30 GeV with the s.c. cavities alone.

In parallel to the installation of the first four s.c. cavities in LEP a first step of upgrading by 32 s.c. cavities is under preparation [6]. Twenty s.c. Nb cavities with cryostats, tuners and couplers have been ordered at industry. An additional eight Nb sputtered Cu cavities (see below) are under construction at CERN. Cavities will be installed on either side of interaction region 2 together with two 1 MW klystron systems and two refrigerator systems.

The 32 cavities alone will produce, at 5 MV/m, a total accelerating voltage of 272 MV and one should be able to reach particle energies of 51 GeV. Together with the Cu cavities an energy of 64 GeV can be reached. This is the limit where some machine components, as for instance the 24 concrete dipole cores in the injection regions and some quadrupoles (low β quadrupoles), need not yet be upgraded.

NIOBIUM COATED CU CAVITIES

Besides the construction and testing of Nb cavities a development programme of niobium coated Cu cavities is pursued at CERN [7,8].

Nb layers, which, due to the Meissner effect need to have only a thickness of about 1 μm, are deposited by magnetron sputtering. It has been shown that this type of cavity is virtually free of thermal breakdowns caused by small localized wall defects and that it is insensitive to small external static magnetic fields. This feature renders superfluous magnetic shieldings as needed for Nb cavities. Altogether it is hoped that this type of cavity should allow a substantial cost reduction.

Four LEP type cavities (with a geometry identical to the one of Nb cavities) have already been fabricated and tested at CERN of which one has been equipped with its He vessel and tested inside its LEP type cryostat. Four more are under construction. Accelerating fields up to 9 MV/m have been reached and all cavities have exceeded the design value of 5 MV/m, making performances comparable to the ones of Nb cavities. Quality factors at low field and 4.2 K ly around 10^{10} while they range at design field between 5 and 7×10^{9} (fig. 1). This is about a factor 2 higher than the ones measured in Nb cavities.

REFERENCES

1. D. Boussard et al., presented at National Acc. Conf., Chicago (1989).
2. D. Bloess et al., presented at 4th Workshop on RF Superconductivity KEK, August 1989.
3. E. Chiaveri, ibidem and CERN/EF/RF 89-1 (1989).
4. P. Bernard et al., CERN/EF 88-6 and Proceedings EPAC, Rome (1988) 958.
5. G. Cavallari, I. Gorine, D. Güsewell and R. Stierlin presented at the 4th Workshop on RF Superconductivity KEK, August 1989.
6. P. Bernard, H. Lengeler and E. Picasso, Proc. ECFA Workshop on LEP 200, Aachen (1986) 29.
7. C. Benvenuti et al., CERN-LEP-VA 88-35 and Proc. EPAC, Rome (1988) 37.
8. Benvenuti et al., presented at the 4th Workshop on RF Superconductivity KEK, August 1989.

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