SUPERCONDUCTING CAVITIES FOR LEP ENERGY UPGRADE

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ABSTRACT
The installation in the LEP collider of 192 superconducting (SC) RF cavities will allow to reach W^-W^+ pair production energy. Cavity prototypes have been developed at CERN, both of Nb sheet and Nb-coated Cu type. The higher performances obtained with Nb-coated Cu cavities have led to choose such technology. Orders have been placed to European industries for the production of the cavities and of the associated power couplers (MC) and higher-order mode (HOM) couplers. We report on the status of the technology transfer and on the results so far obtained with the start-up of the production. A new facility for the reception test of the bare cavities and of the complete modules has been prepared. It will be used later for the maintenance of the superconducting cavities installed in the collider.

1. INTRODUCTION

The LEP energy upgrade to W pair production energy requires the installation of 192 superconducting cavities operating at a nominal accelerating field of at least 5 MV/m [1]. The first 12 cavities, 2 made by industry and 10 by CERN, have been installed and are operated since 1989. A second set of 20 Nb sheet cavities has been delivered by industry and is being tested before assembling into modules at CERN. For these cavities a nominal gradient of 5 MV/m and a quality factor of $3 * 10^9$ was specified.
In the meantime the Nb-coating of Cu cavities has been pursued [2,3] and is now giving excellent results. It has been decided to order the remaining 160 cavities based on this technology, with a nominal accelerating field of 6 MV/m and a quality factor of $4 * 10^9$.

2. THE Nb SHEET CAVITIES

In 1989 a contract was awarded(*) for the construction of 20 Nb sheet 4-cell cavities at 352 MHz. The cavities are delivered fully assembled in the cryostat and are equipped with frequency tuners, temperature gauges and RF probes but without power couplers and HOM couplers to allow precise measurement of the cavity Q. Separate contracts(**) were awarded for the fabrication of the coaxial power couplers (MC) and of the HOM couplers.
So far all the cavities have been delivered and tested. Ten have surpassed the design figures of $E_{acc} = 5$ MV/m and $Q = 3 * 10^9$. Four developed a thermal quench at ~ 4.5 MV/m. As the cavities are already assembled in the He tank it was not possible anymore to apply diagnostics (Temperature Mapping [4]) in order to identify the defects. Six others have shown heavy electron loading. All the rejected cavities have been CP polished and rinsed. Nine have been tested again and have also surpassed the design figures.
The measurement protocol foresees that He processing is applied as soon as non resonant e^- loading is detected. The processing times required to reach the design figures show a very large spread (fig. 1).

(*) CERCA (F).
(**) SICN (F).

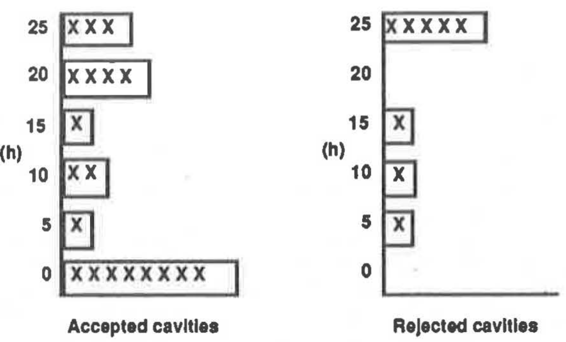


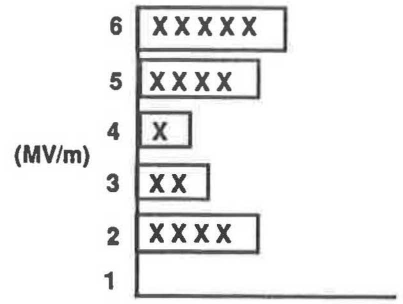
Fig. 1

The assembly of four cavities into one module and the installation of the MCs and HOMs is made at CERN. The first module has been assembled and during the tests the specified field levels could not be reached due to heavy e^- loading. In a parallel test, insufficient cooling for some of the HOMs was also detected. The latter problem has been fixed since then, and the module is going to be tested again as soon as the test area becomes available.

3. THE Nb-COATED Cu CAVITIES

The Nb-coating of Cu cavities offers a number of advantages over bulk Nb, among them a higher Q vs E_{acc}, better stability against thermal defects and insensitivity to ambient magnetic field [4].
The production of the 160 cavities has been awarded to three European companies(***). Of these, two have already experience in building superconducting cavities and the third is a supplier of high-technology equipments to the particle physics community.
Each contractor has to install state-of-the-art magnetron sputtering equipment, electron beam welding, a fully automatized chemical polishing plant, semiconductor grade high-purity water plant, 60 m^2 at class 100 clean room and, last but not least, to train a team to all the activities required to reliably build superconducting cavities and to assemble them into 4-cavity accelerating modules.
Many prototypes have been delivered by each contractor. Most did not reach the design figures, but significant progress has been achieved and many prototypes already surpass the Nb sheet cavities (fig. 2). In total, five prototypes have met the design figures (fig. 3).

(***) Ansaldo (I), CERCA (F) and Siemens (D).



Maximum field with Q > 4 * 10^9
Fig. 2

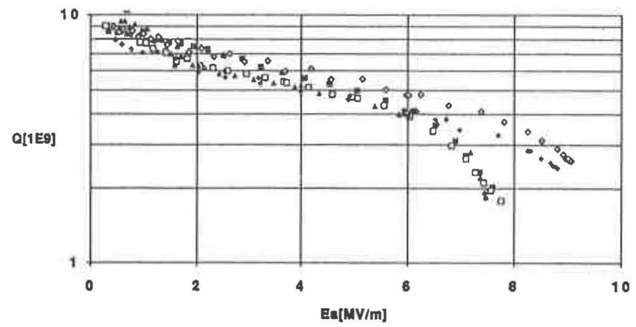


Fig. 3

4 POWER AND HOM COUPLERS

The experience gained so far in LEP and the planned increase of the LEP intensity have pushed for the development of variable MCs [5]. The design range of the coupling factor ($3 * 10^5$ to $3 * 10^9$) has been achieved and 8 units have been built. They have been tested up to 180 kW in TW mode on the test bench and the coupling factor has been verified on an SC cavity.
An additional advantage of using such variable couplers is the possibility to measure the Q vs E_{acc} of cavities installed in the machine and thus to identify the eventual degradation of a cavity during operation.
In anticipation to planned increases of bunch numbers in LEP, which require enhanced HOM damping and will result in increased HOM power, work to upgrade designs has been persued. Fully demountable couplers which produce external Q values below 10 000 for all significant HOMs have been built in a preseries [5].
In a recent test run on a LEP cavity, after some processing, two such couplers have been operated at a gradient of 6 MV/m and with 130 W of 506 MHz HOM power.
But, during cavity processing, i.e. under conditions of strong electron loading of cavity and couplers, leading to cavity and coupler quenches, thermal recovery of couplers was unconveniently slow. Work to provide more cooling power than the actual 5 W per coupler is underway.

5. CAVITY TEST FACILITY

Each Nb/Cu cavity undergoes first a vertical test after the coating and a second one when assembled in a 4-cavity module, both with critical coupling and RF input powers up to 300 W. A final test is foreseen at high RF input powers (100 kW) before installation in the machine.
A complete cavity test requires of the order of 10 000 ℓ of LHe and may last one week. Such large quantities of LHe are possible only with an on-line cold box under automatic, closed loop operation.
A new test facility has been prepared with 4 vertical stands for bare activities tests and 2 horizontal stands for module test. Each stand may be operated independently of the others to achieve high turnover. A new 6 kW cold box(*) has been installed and commissioned.

6. CONCLUSION

The preparation of the superconducting cavities for the LEP energy upgrade is in progress and it is expected to start-up the series production already this summer.
The first modules from each of the contractors will follow during this fall, and the installation in the machine is foreseen during the 1993 shutdown.

Acknowledgements

The progress so far achieved in preparing the cavity production has been possible only by the enthusiastic faith of the main contractors and of their subcontractors.
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Many groups of CERN (AT-CV, MT-ESI, ST-IE) and our technicians (AT-RF, AT-VA, MT-SM) have contributed to the setting up of the test facilities and take part to the preparation and to the tests of the cavities with great competence. Their contribution is greatly acknowledged here.

References

[1] C. Wyss, "Status of the LEP energy upgrade", proc. of the 3rd European Part. Acc. Conf., Berlin (1992).

[2] G. Cavallari et al., "Status report on superconducting Nb cavities for LEP", proc. of the 5th Workshop on RF Superconductivity, DESY (1991).

[3] C. Benvenuti, "Superconducting coatings for Accelerating RF Cavities", 5th Workshop on RF Superconductivity, DESY (1991).

[4] C. Benvenuti et al., "RF superconductivity at CERN", proc. of the 2nd Workshop on RF Superconductivity, CERN (1984).

[5] E. Haebel, "Couplers, tutorial and update", proc. of the 5th Workshop on RF Superconductivity, DESY (1991).

(*) Air Liquide (F).