Superconducting Cavities for the LEP energy upgrade

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Abstract

The technology of sputter coating of Cu cavities with Nb has been developed at CERN. The advantages of this technique have led CERN to order 168 of such cavities in industry. After an initial phase of technology transfer and of prototype development, the series production has been started in fall 92 by the three contractors. The results of the bare cavity tests are reported. Fixed and movable 120kW power couplers (MC) have been designed, manufactured and put into operation. Various models of higher order mode (HOM) couplers have been developed to cope with foreseen increase of the beam intensity. Special care is given to the conditioning of power couplers and of HOM couplers before installation in the machine.

INTRODUCTION

In total 192 superconducting cavities operating at accelerating fields of about 5MV/m are required to reach colliding beam energies suitable for W- W+ pair production physics. In 1988 it was decided to start with 24 cavities of bulk Nb while the technology of sputter coating Nb onto Cu was being developed. In 1990 the results obtained with the NbCu prototypes were positive enough to start the production of 168 sputter coated cavities [1]. The cavity frequency and the geometry were kept as for Nb cavities but a number of changes were introduced in the cryostat [2], the HOM coupler [3] and in the MC design.

THE BULK Nb CAVITIES

All the Nb cavities have been delivered [5] and accepted. The design figures were $Q_o \geq 3.10^9$ at 5MV/m and 4.2 K. The cavities have then been assembled at CERN in four-cavity modules and equipped with MC and HOM couplers. The final tests performed after assembling have shown a systematic degradation of the cavity performances mainly due to non resonant electron loading (field emission) such that the operation at 5MV/m could not be guaranteed. A new rinsing of most of the cavities becomes necessary.

In the mean time movable power couplers have been developed. It has been decided to launch a consolidation process of the bulk Nb cavities in order to install cavities of improved and more reliable performances (cryogenic circuit, capability of higher beam current, matching of RF power to beam intensity). A new planning has been established for the installation of the Nb modules in the 1993-94 winter shutdown.

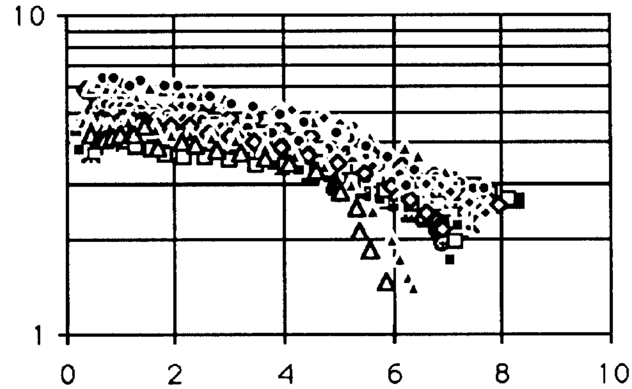

Fig. 1 - Bulk Nb cavities: Q_o[E9] vs Eacc [MV/m]

THE Nb COATED Cu CAVITIES.

Among the advantages of the sputter coated cavities one should mention [1] the higher Q_o the stability against quenches, the unsensitivity to low ambient magnetic fields [9]. The design figures could be set to $Q_o \geq 4.10^9$ at 6 MV/m and 4.2 K, somewhat higher than the ones for bulk Nb cavities in order to provide a reliable operation at 5 MV/m.

The contract for the 168 cavities has been split to three companies. Almost two years have been necessary in order to install the required facilities [5], transfer the sputter coating technology, train the teams and start the production. At present more than 30 bare cavities have been accepted (Fig. 2) and two 4-cavity modules have been delivered.

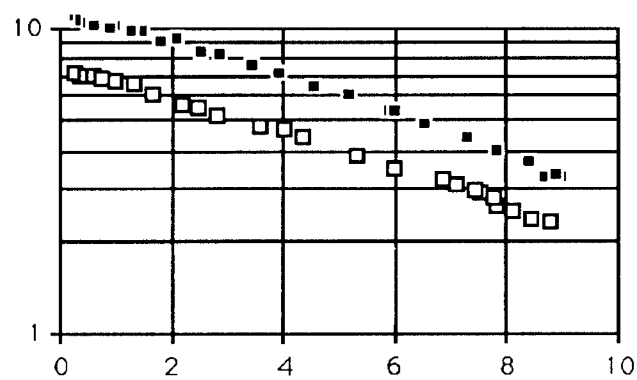

Fig. 2 - NbCu accepted cavities, best and worst : Q_o vs Eacc

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The problems encountered so far with the bare cavity test may be grouped in four categories:

• field emission already at low fields, coming from poor final rinsing or handling accidents. If the parameters of the rinsing water (resistivity, particle content, germs and Total Organic Carbon) are carefully controlled, gradients up to 9 MV/m can be obtained after a short time of "RF processing" in nearly all cases, without significant electron loading [6,12]. The gradient is limited by the available RF power. In the exceptional other cases He processing is applied to overcome field emission, otherwise a new rinsing is performed (Fig. 3).

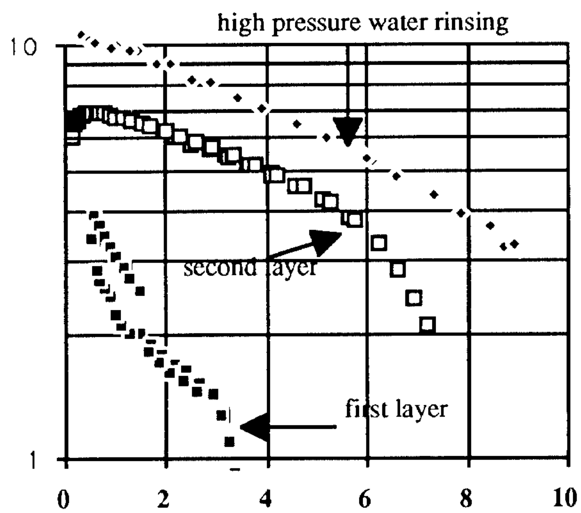

Fig. 3 - Successive coatings: Q_0 vs Eacc

• blisters, due to bad adhesion of the Nb film on the Cu substrate. The Q_0(Eacc) curve suffers from stepwise degradation when rising field, sometimes also from hysteresis (Fig 3). At high fields the blister eventually emits electrons that cannot be processed away by RF and He processing. Removing the blister by e.g. high pressure water rinsing [10] may bring the cavity to working condition. It also shows a poor adhesion of patches of the film. Temperature mapping is routinely applied in order to identify the defect position. The coating is usually removed by chemistry and a new coating is applied after a 20µm etching process. It has been noticed that successives coatings led to improved Q_0 values (Fig 3). This problem has been traced to impurities deeply implanted into the Cu sheet during the lamination process. An electropolish etching of 120µm instead of 80µm reduces drastically the number of blisters.

• poor Q_0 at low fields. After optical inspection the film is removed and a new coating is applied after a 20µm chemical polishing.

• good Q_0 at low fields but higher non quadratic losses [6] reduce the Q_0 at 6MV/m below the design figures. The mechanism is not yet fully understood [6,10].

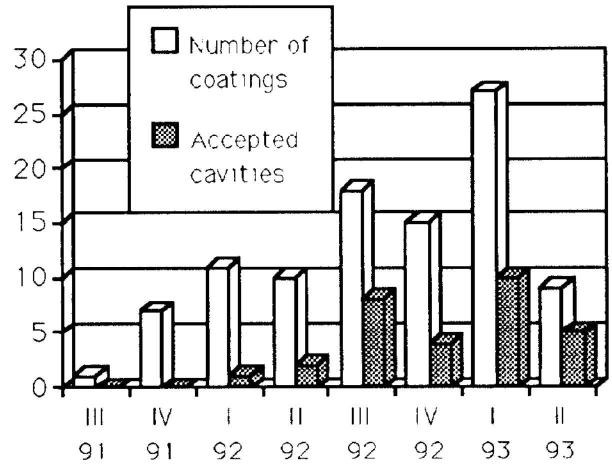

Fig. 3 - Production and acceptance rate of NbCu cavities

THE MOVABLE POWER COUPLER

The optimum coupling of the RF power to the cavity is determined by the beam intensity as well as the maximum accelerating voltage. Therefore, future beam intensity increases would ask for a modification of the coupling factor to avoid excess power consumption. The replacement of a MC on an installed cavity is potentially harmful as it may contaminate the cavity. The present movable coupler design [3] allows to change the coupler's Qext from 3.10^9 to 3.10^5. A byproduct is the possibility to correct the scatter in cavity coupling and to measure the Q_0 of cavities fully assembled or even already installed in the accelerator. It is precisely in this configuration that the final acceptance tests of the four-cavity modules are performed. The MCs are conditioned on a dedicated setup at room temperature under high vacuum up to 180 kW in travelling wave operation first and in future also in standing wave mode to cover all the SC cavity operating conditions.

THE HIGH ORDER MODE COUPLERS

Various HOM couplers have been developed so far [3], two are best suited : an antenna type (Type 1) for Nb cavities with Qext of 25000 at the TM011 mode, suitable for four bunch operation and beam intensities up to 8mA, and a hook type (Type 5) for NbCu cavities with Qext of 6000 at the TM011 mode, suitable up to 8 bunches per beam and beam intensities up to 12 mA.

The cooling of the HOM couplers has been found marginal during cavity conditioning under heavy e- loading although it is largely sufficient for normal operation. Improvements are in progress.

THE CRYOSTAT

The basic concept of the original cryostat layout has been kept [2] as it allows a modular assembling of the cavities in cryomodules, the access to the cavity accessories and to the cabling irrespective of the cavity vacuum. A number of changes has been introduced:

• there are three reinforcing beams instead of one, the structure has been made stiffer such that the modules may be rotated around the longitudinal axis during the transport in the accelerator tunnel.

• a vacuum flange is provided in line with each HOM coupler allowing, in future, counterflow cooled, high power rigid coaxial lines for the HOM coupler, in case the HOM power exceeds 400W per cavity. The actual RF cables, rated to 100 W in vacuum, have been made shorter (80cm).

• the Cu radiation shields have been removed and a total of 80 sheets of superinsulation, in two layers, are installed. The cryogenic static losses are now about 16W per cavity [11] to be compared to 50 W dynamic losses per cavity at 5MV/m.

CONCLUSION

The Nb coated Cu cavity production has encountered some initial difficulties but the success rate on the bare cavity production is above 50% and more than 30 cavities have been accepted. The cooling of the HOM couplers has been found insufficient under heavy e^- loading and new cooling schemes are being designed. Two cryomodules, whose installation is foreseen for September '93, have been delivered by industry and are under acceptance test.

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The supply of large quantities of lHe by he cryogenics group has been a key issue for the testing of a large number of cavities in a few months.

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