First Cold Test of TESLA Superconducting RF Cavity in Horizontal Cryostat (CHECHIA)

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Abstract

In the framework of the TESLA project, the horizontal cryostat (CHECHIA) was built to test a superconducting RF cavity equipped with its helium vessel, magnetic shielding, cold tuner, main coupler and higher order modes couplers under realistic conditions before final assembly of eight cavities into TESLA Test Facility cryomodule. We report the results of the first cold tests in CHECHIA, performed at DESY with a 9-cell cavity (C19) to be used in the TTF injector. At 1.8 K, in CW operation the cavity reached accelerating gradient of 19 MV/m with $Q_0 > 10^{10}$. In the previous test in vertical dewar the maximum field obtained was Eacc~22 MV/m with heavy field emission ($Q_0 < 2*10^9$). Additional measurements of mechanical stability under RF operation (frequency variation with He pressure, Lorentz detuning) and cryogenic and electric measurements of power dissipation are presented.

1 INTRODUCTION

TESLA [1] is an international collaboration to establish a technical basis for a future $e^+ - e^-$ linear collider using L-band (1.3 GHz) superconducting RF structures. The TESLA Test Facility, (TTF) including an experimental linac (consisting of 32 nine-cell solid Niobium cavities) operating at 1.8 K[1], and the infrastructure to process and test the superconducting RF cavities is being constructed in Hall 3 at Deutsches Elektronen-Synchrotron DESY in Hamburg.

In the framework of this project, a horizontal test cryostat CHECHIA (Cryostat Horizontal d'Essai de Cavités Habillées et de l'Instrumentation Associée [2]) was built for testing superconducting RF cavity equipped with its helium vessel, Cold Tuning System (CTS), main coupler and higher order modes (HOM) couplers under realistic conditions before final assembly of eight cavities into TTF cryomodule.

In this paper we report the results of the first cold tests in CHECHIA, performed recently at DESY with a 9-cell cavity C19, made by CERCA, to be used in the injector of the linac. After providing some detailed information of cavity manufacturing and treatment prior to cold test we present the results of the first cold tests of cavity performance in CHECHIA and compare it with the results previously obtained during cold tests in vertical dewar. In addition, the results of power dissipation measurements, mechanical stability, Lorentz forces detuning effects and performance of CTS are discussed.

2 C19 MANUFACTURING AND TREATMENT

Cavity C19 was manufactured by CERCA (France) and heat treated at Saclay. 1.9-mm thick Niobium sheets of RRR=250 were used in fabrication of this cavity. Half-cells have been stamped and machined and Electron Beam (EB) welded along the iris to form a "dumb-bell" structure. In addition, a stiffening ring was EB welded to provide mechanical stability. The structures were then placed in the oven at 1300° C, where they underwent a 16 hour titanification process on both sides, resulting in RRR increase to 590. After a chemical etching the "dumb- bell" structures were welded along the cells equator to form the cavity. The cavity C19 was then shipped for cold testing to TTF where it was chemically polished (Buffered Chemical Polishing - BCP - 120µm of material removed) and tuned to the specified frequency

[1] TTF specifications for superconducting cavities are: $Q_0 = 3*10^9$ at Eacc=15MV/m.

(field flatness ~0.93). After tuning operation, a standard (20μm) BCP followed by rinsing with high pressure (100 bar) ultrapure water (HPW) of resistivity >18MΩ was then applied, before cavity installation in vertical dewar. At 1.8 K, the CW measurement showed a satisfactory performance of this cavity: no field emission was observed and $Q_0 > 10^{10}$ was measured up to Eacc=15MV/m (quench limit). In the subsequent test, after High Power Processing (HPP), the cavity C19 reached accelerating gradient of Eacc~22MV/m but heavy field emission, observed for Eacc>15MV/m, limited the quality factor to $Q_0 < 2*10^9$ at max. field (Fig. 2). Following these tests C19 was sent to Lufthansa workshops where a Liquid He (LHe) vessel made of Ti was EB welded around it. At DESY the cavity was re-tuned; measured field flatness was better that 0.83.

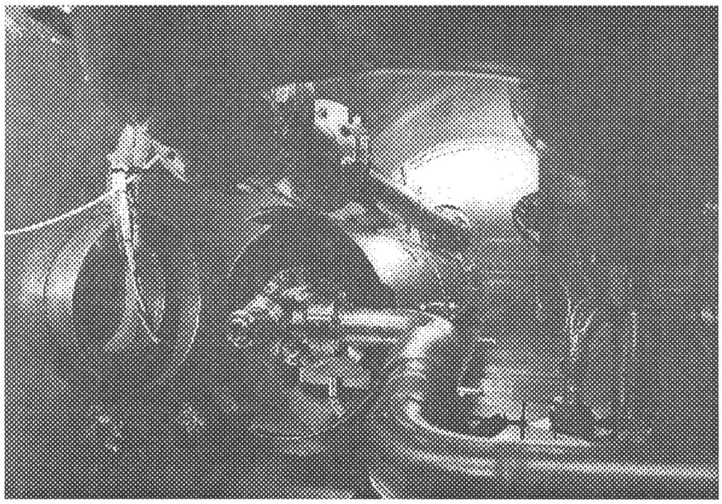

Fig. 1 View of CHECHIA interior with C19 installed in its LHe vessel and magnetic shielding.

3 COLD TESTS OF C19 IN CHECHIA

3.1 First cool-down of C19 in CHECHIA

Cavity C19 with its LHe vessel, Cryoperm magnetic shielding (a residual magnetic field $B<5*10^{-7}$ T was measured inside shielding), and Cold Tuning System (CTS) was installed for the first time in CHECHIA (Fig.1) on 1-Sep-95. The goal of this test was to perform all checks of cryogenic systems and vacuum connections and to check the installation procedure. A light (~5 μm) BCP, followed by rinsing by ultrapure HPW was applied. During installation work it was necessary to re-open several flanges. After a successful cool-down to 1.8 K (TESLA nominal operating temperature), CW measurement of Q_0 was performed to check the cavity performance. Although the initial Q_0 was high ($2*10^{10}$), a heavy field emission was observed at Eacc >5 MV/m, indicating cavity contamination. Cryogenic and electric measurements of power dissipation and tests of mechanical stability (frequency vs. He pressure) performed during this first cool-down are discussed in section 3.3. Because of CTS failure, the cold test was interrupted and CHECHIA was warmed-up to room temperature. The electrical motor was exchanged in the CTS and cavity was HPW rinsed prior its re-assembly in CHECHIA. A local clean room was installed in CHECHIA to prevent the cavity contamination during its connection to CHECHIA vacuum system.

3.2 C19 Performance at 1.8 K

The second cool-down took place on 4-Oct-95. CW measurement of Q_0 was performed at 1.8 K to check cavity performance. Quench occurred at Eacc~19 MV/m and Q_0 remained high as in the previous test in vertical dewar, where the cavity is immersed in the LHe bath. Fig. 2

shows C19 performance at 1.8 K, measured in CHECHIA, compared with the best results from previous tests in vertical dewar.

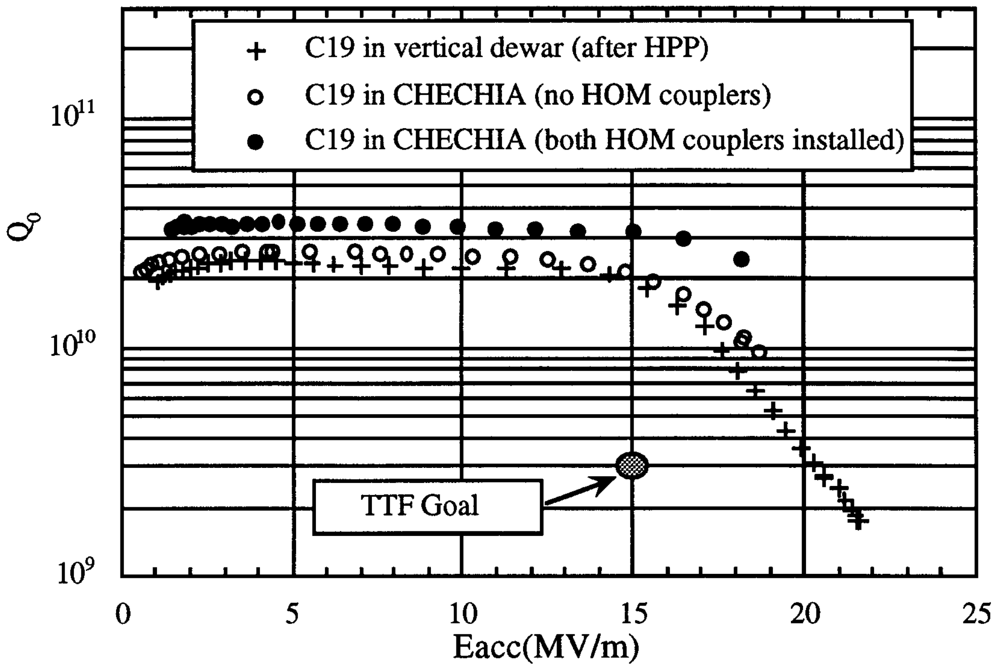

Fig. 2 C19 performance in CHECHIA and during tests in vertical dewar. Max. Eacc is limited by quench.

The third cold test in CHECHIA was performed on 16-Nov-95. Again C19 was HPW rinsed before assembly in CHECHIA. Both Higher Order Modes (HOM) couplers, designed at Saclay [3] and manufactured by S.I.C.N., France, were installed, and C19 was cooled down to 1.8 K. CW measurement of Q_0 performed at 1.8 K showed no difference with the previous tests of the cavity performance. (see Fig. 2).

3.3 Measurement of Power Dissipation

A cavity's quality factor, Q, is a measure of RF power loss. As long as the cavity is equipped with a high Q antenna, power dissipated in the cavity walls during a CW RF operation, P_{diss} can be measured by electric and cryogenic method. In the former, P_{diss} is determined from measurements of incident, transmitted and reflected power and decay time constant. The cryogenic method, described in [2], is based on measurements of the He flow rate out of cryostat.

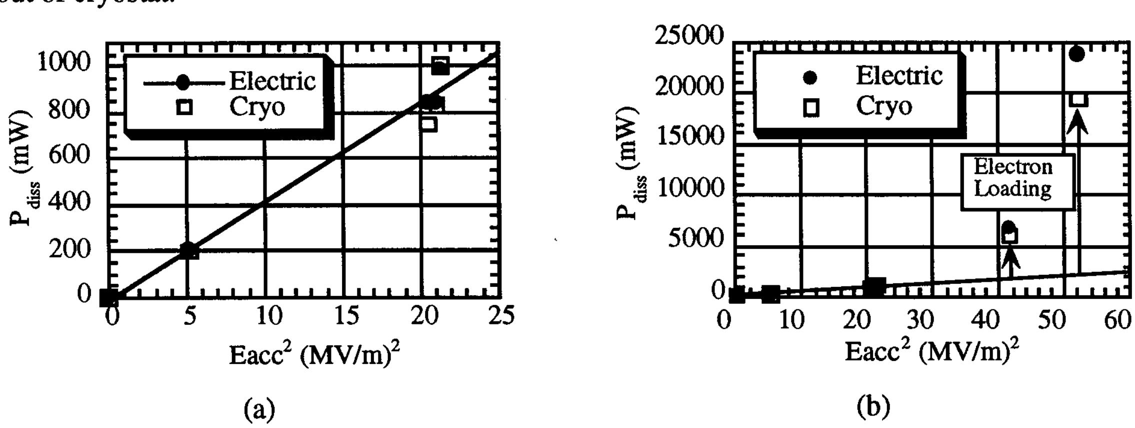

Fig. 3 Measurement of CW RF power dissipation in C19 for low (a) and high (b) field.

Because the input couplers of cavities installed in the linac will have the coupling coefficient not appropriate for electric measurements of P_{diss} it is important to validate the cryogenic method as a source of information on cavity quality. During the first cool-down we have therefore performed measurements of power dissipated during CW RF operation using both methods. Results of this measurements are presented on Fig. 3. The solid line presents a linear fit to data from electric measurements. For low field both methods give the results that agree within few mW. However, when electron loading from field emission, indicated by a departure of P_{diss} from square law, rises for Eacc > 5 MV/m - results from both methods start to diverge. The difference could be explained by some power taken away by electrons and X-rays which is not dissipated at 2 K level.

3.4 Test of Mechanical Stability

The bandwidth of the loaded cavity at the specified $Q_{EX}=3*10^6$ is about 433Hz [1]. Therefore a special attention was devoted during cavity design and fabrication to assure mechanical stability of the cavity and its LHe vessel. During normal operation, cavity deformation resulting in the frequency shift may be caused by a change of He pressure in the cavity vessel and by the Lorentz force of the pulsed electromagnetic field (Lorentz force detuning). We have measured the both effects during cold tests of C19 in CHECHIA at nominal operating temperature 1.8 K. Fig. 4a shows the effect of cavity deformation caused by He pressure change in the LHe vessel. The solid line represents a linear fit to the data. This is relatively good agreement with the calculated value of 15 Hz/mbar if one considers the reduced wall thickness[2]. and the non rigid longitudinal constraint of the cavity.

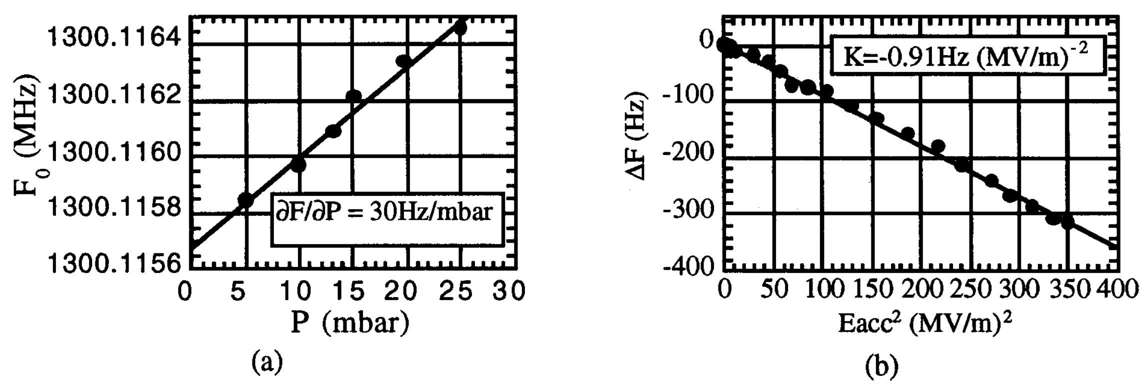

Fig. 4 Test of mechanical stability of C19. Solid line shows a linear fit to data. (a) Effect of C19 deformation caused by He pressure change. The measured frequency shift gradient is ∂F/∂p= 30 Hz/mbar. (b) Lorentz force detuning effect in C19 measured in CHECHIA.

Effect of Lorentz force detuning is presented on Fig. 4b. The frequency shift recorded during RF field rise was corrected by taking into account a possible frequency change related to the He pressure fluctuation as shown of Fig. 4. The linear fit to the data (solid line) determines the Lorentz force detuning coefficient K = -0.91 which is very close to the value of K= -1 anticipated from finite elements analysis [1].

3.5 Cold Tuner System

The Cold Tuner System (CTS) assembly consist of electric step motor with a gear box connected to a lever and attached to the cavity. By actuating the step motor one can change the cavity length, and thus its frequency. The total possible displacement is 3 mm corresponding to ΔF=0.9 MHz. The CTS was tested with the step motor running continuously for about 40 min. covering about 30% of designed frequency shift. The measured CTS factor was 0.8 Hz/step (see Fig. 5). The motor temperature rose to 350 K during this operation because of poor motor

[2] C19 was manufactured from Nb sheets of 1.9 mm thick while the linac cavities are being fabricated with sheets of 2.65 mm thickness.

cooling resulting in motor damage. A better motor cooling system is presently being prepared for the next test of the CTS.

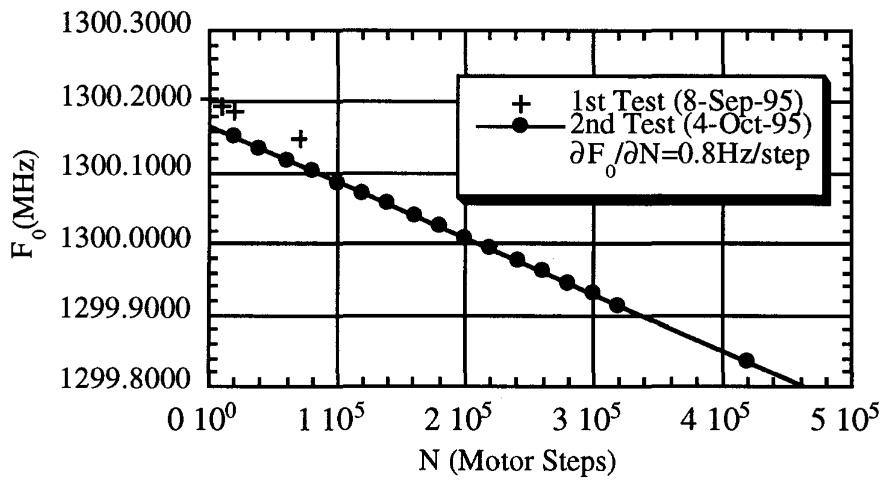

Fig. 5 Cold Tuner System (CTS) test. Solid line is a linear fit to data.

4 CONCLUSIONS

Cavity C19 foreseen for the TTF injector was successfully cold tested in the horizontal cryostat CHECHIA under realistic conditions. Cavity performance was found to be very similar to the results obtained during tests in vertical dewar, when the cavity was immersed in the LHe bath. Power dissipated during RF operation was measured by electric and cryogenic methods yielding similar results. Mechanical stability of C19 was found to be in agreement with design.

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