Status of the Superconducting Cavity Program for HERA

B. Dwersteg, G. Enderlein, W. Körber, A. Matheisen,
W.-D. Möller, D. Proch, D. Renken and J. Sekutowicz
Deutsches Electronen-Sychrotron DESY
Notkestraße. 85, 2000 Hamburg 52, Germany

Abstract

Superconducting 500 MHz cavities have been developed at DESY for the purpose of increasing the electron beam energy of the HERA storage ring. The system consists of 16 cavities, 8 cryostats and a LHe distribution line. We report about the test of the components and give first results of operating experience.

1 Introduction

At DESY a development programme had been started to produce 500 MHz superconducting cavities for HERA. The general layout and detailed design are described in [1] and [2]. Three 4-cell cavities and two cryostats were fabricated by industrial firms (DORNIER, INTERATOM, NTG). A series of RF-and cryogenic measurements and a storage ring test in PETRA were carried out. After this prototype programme a pilot project of 16 cavities and 8 cryostats was approved. This project will gain operating experience for a possible further upgrading with superconducting cavities. Cavities and cryostats were delivered until end of 1990. The individual components were tested at DESY and installation in HERA started in January 1991.

2 Measurements

2.1 Cavities

All cavities were produced by industry including the final chemical cleaning. Before cooldown the cavities are prepared in a dust free room at DESY (HOM-coupler tuning, assembly of couplers and antennas). The accelerating gradient E_{acc} and the quality factor Q are measured at 4.2K in a horizontal cryostat. Usually rf-processing(about 1h) or, in more severe cases, He-processing (several hours) was needed to push the field emission barrier beyond the specified value of $E_{acc} = 5MV/m$. After this acceptance test a pair of two cavities was assembled into one cryostat. At this stage the high power input couplers are added to the cavities. The complete module is cooled down and tested with 100 KW forward power. This is the final system test before installation in HERA.

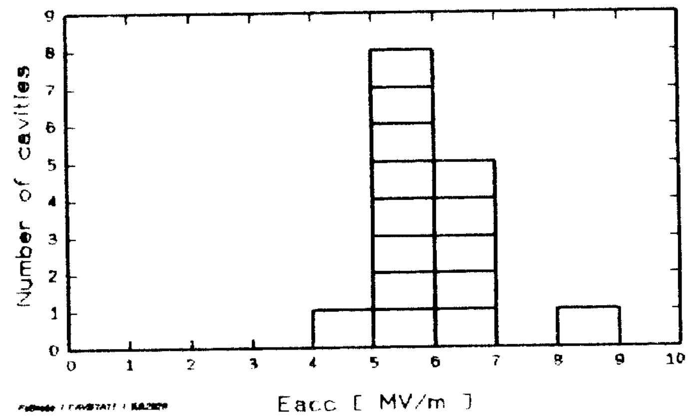

Figure 1: Maximum accelerating gradients E_{acc} (MV/m) reach in horizontal tests.

Fig.1 shows the maximum fields reached. With the exception of two cavities (quench at the equatorial weld) all cavities were limited by available rf-power or increased He-losses. We experienced that the surface resistance is increased after second or more cooldowns. A typical example is shown in Fig.2.

This cavity has been cooled down several times, no changes have been made other than temperature cycling. With another cavity the accelerating field was kept below the onset of field emission. Thus radiation damage could be excluded as reason. It turned out that the increase of surface resistance is enhanced by a longer cooldown time. The typical cooldown time from 300K to 4.2K was 24 hours, the shortest possible at the testarea was 8 hours. The increase of surface resistance ranged from 50nΩ to 400 nΩ. Meanwhile this Q degradation has also been observed at several other laboratories (fot more details see [3]). The most likely explanation is the formation of normal conducting hydrogen precipitations at the Nb surface around 100K. Obviously the high thermal conductivity Niobium (high RRR) supports this effect by the reduced O-content thus offering less trapping centers for the dissolved Hydrogen. Our investigations conclude that the Niobium is polluted by Hydrogen during the chemical cleaning processes [3]. Degasing at 800C cannot be applied to our cavities at the final stage of production because of brased stainless steel

0-7803-0135-8/91$01.00 ©IEEE

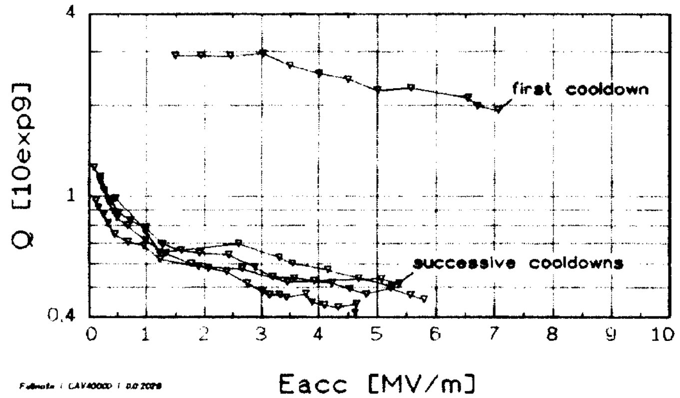

Figure 2: Q degradation after several cooldowns different temperatures)

parts at flanges and at the He-tank.

At the average the cavities dissipate a factor of three more power as specified at 5MV/m (40 Watts). It was decided to install the cavities in HERA and gain operating experience. The HERA refrigerator will allow a faster cooldown as compared to the test area facility. Thus we might reduce the Q degradation effect. In parallel we will work on Hydrogen cleaning process. Experiments on samples show that the hydrogen content can be reduced by chemical methods [3].

2.2 Input coupler

The maximum input power of one 4-cell cavity is restricted to 100KW to assure some operating conditions of the coaxial input coupler[4].The coupler is carefully trained before assembly to the cavity and is monitored during operation to avoid a brake of the ceramic disk. During training at room temperature two couplers are attached together. A lot of multipacting levels are detected up to 30 KW by electron pick-ups and light sensors. They are overcome by pulse processing in typically one day. Training stops after 150KW is reached under continuous wave conditions. Observations by a mass-spectrometer conclude that hydrogen desorption play a dominant role during rf processing. 14 couplers passed conditioning without problems, one out of two repaired couplers (mechanical damage before assembly) was rejected because of excessive heating at the ceramic around 80KW. The conditioned property is preserved during assembly in the dust free room. An additional rinsing with dust free water, which might be desirable along the assembly procedure, turned out to require a new training process.

2.3 Cryostat

The stand by heat load of the prototype could be reduced by several improvements: use of titanium instead of stainless steel at the fixpoint construction, modified heat exchanger at the room temperature transition of the beam

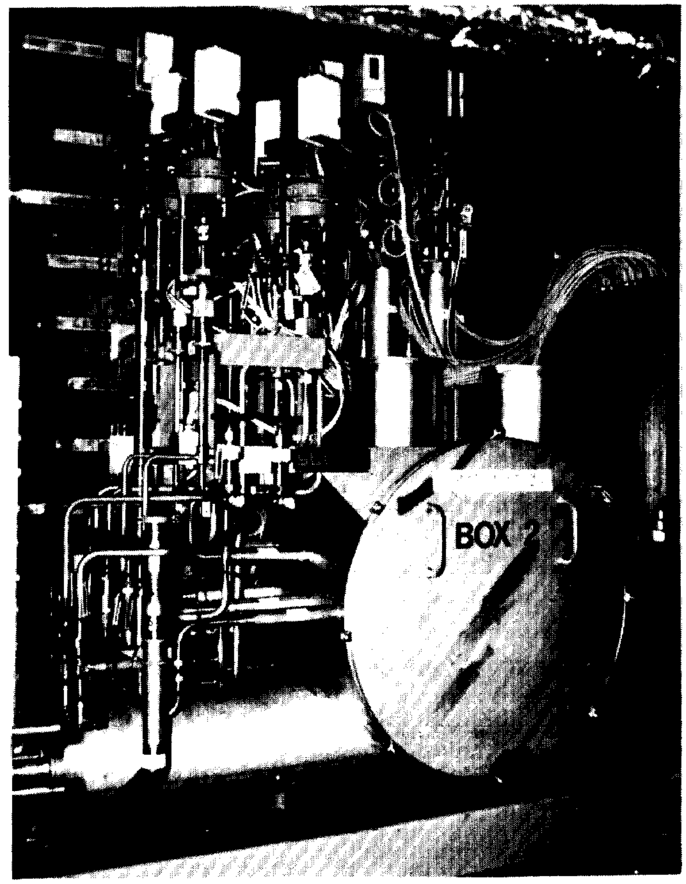

Figure 3: Valve box during installation in the HERA tunnel

pipe and the input coupler and some changes at the 40-80K radiation shield. The static heat load has been measured to 18 watts at 4.2K and 70 watts at 40-80K. The insulation vacuum after cooldown is in the range of 10^{-7} mbar with the pump closed.

3 HERA Installation

3.1 Cryogenics

The liquid helium is delivered by the central refrigerator plant of HERA. The distribution system consists of a subcooler, 120m transfer line and 8 valve boxes, one for each cryostat. Fig.3 shows one of the valve boxes during installation in the tunnel. Each cryostat can be cooled down or warmed up by means of its valve box. In Fig.4 the flexible transfer lines from the valve boxes to the cryostats can be seen on top of the cryostats.

In total 100 analog or digital valves and 500 status signals have to be monitored and controlled. This is done by the same computer system as for the refrigerator plant [5, 6]. The distribution system was installed until end of 1990 and is under operation since January 1991.

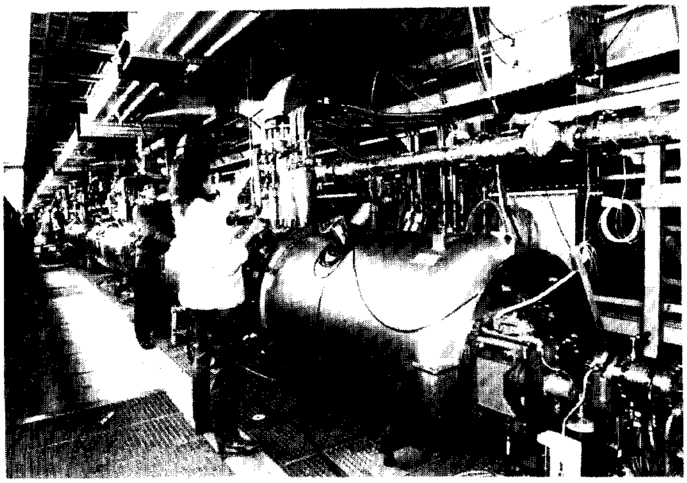

Figure 4: Cryostat installation in HERA

3.2 Rf. power system

The output power of two klystrons (up to 1.6 MW) is added and transfered to the HERA tunnel by a WR 1800 waveguide. From this mainline 9 directional couplers and 6 magic tee dividers feed the individual cavities. Each cavity has a three stub transformation to vary the coupling coefficient as well as the relative rf-phase. In Fig.4 the rf distribution system can be seen in the upperpart of the tunnel and on the right hand side of the cryostat. Each cavity has its own slow frequency tuner to compensate for drifts of the resonance frequency or for beam loading.

3.3 Interlocks

The complex system of cryogenics, high rf power and beam interaction needs a lot of monitoring to assure a correct operation of all elements. A lot of standard data (e.g. vacuum, temperature) are measured and interlocked by different computers. Some critical data like pressure in the LHe tank have an additional hardware link to the interlock relay.

Special care has to be taken to avoid a break of the input window and to switch off the rf power in case of a quench. The window might break due to local heating (sparks, plasma discharge or lossy points). Monitors for the window temperature (infrared detector) light sensors near the ceramic (photo-fets) and e^- pickups in the vacuum part of the input coupler interlock the klystron power.

In case of a quench the dumped stored energy amounts to only 10 joule. The strong coupling of the input coupler, however, drives the whole cavity normal-conducting so that all klystron power (up to 100KW) will be dumped to the 4.2K Helium. The onset of a quench is monitored by the increase of the presure in the LHe circuit of the cavity and interlocks the klystron power.

4 Commissioning

The helium distribution system, 4 cryostats and the control and interlock systems have been installed in HERA before the end of the last shut down (end of February 1991). The next two months were mainly devoted to operate the p-ring of HERA. During this time the cavities were cooled down and operated (without beam) whenever this was not conflicting the p-ring activities. The cryogenic and rf control-loops were adjusted and the couplers and cavities were trained by rf pulse processing. At the time of writing this paper a total voltage of 32.6 MV hase been established.

3 more cryostats are ready for installation in HERA during the next shut down in May 1991. The last cryostat (two cavities) will remain at the test area. It is the aim, to develop an additional treatment to clean the Niobium from the Hydrogen contamination which is the reason of Q-degradation.

References

[1] B. Dwersteg et al., Proc. of the IEEE PAC, Washington D.C March 1987

[2] B. Dwersteg et al., Proc. of the Europ. PAC, Rome, June 1988

[3] G. Enderlein at al., This Conference

[4] B. Dwersteg et al., Proc. of the 4th Workshop on RF Superconductivity, KEK, Tsukuba, Japen, August 1989

[5] M. Clausen et al., Proc. of the Europ. PAC, Nice, June 1990

[6] B. L. Norris, DESY M-90-04, July 1990