STATUS REPORT OF THE SUPERCONDUCTING 5-CELL ACCELERATION STRUCTURE AT CERN

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Summary

At CERN a 5 cell 500 MHz superconducting accelerating cavity has been constructed. At present the cavity is installed in the PETRA storage ring at DESY for a test run which will start middle of March. The cavity is equipped with a high power coupler and with 5 higher order mode couplers, two of the loop type and three of the antenna type. Frequency tuning and regulation are achieved by varying the length of the two end-cells. In a test of the complete cavity-cryostat system at CERN, acceleration fields of 2.8 MV/m and Q_0-values above 10^9 have been reached. The cryostat losses remained below 10 W.

The 5-cell cavity

The cavity geometry and the location of the main coupler, of the higher order mode (hom) couplers and of the r.f. probes is shown in fig. 1. Some cavity parameters and experimental results are listed in table 1. The iris opening has been chosen so to obtain a sufficient field flatness with the mechanical tolerances obtainable by our spinning and welding methods described in more detail in ref. 1. The design and the parameters of the main coupler and the hom couplers are described in ref. 2. Each cell is equipped with one hom coupler of either the antenna or loop type. The initially foreseen arrangement[3] had to be changed because the TM_{011} mode, and to a lesser extent the TM_{111} mode showed a strongly asymmetric field distribution (due to a slightly different geometry of cell 4). In fig. 1 the new arrangement is shown. In table 2 a few parameters relevant to the hom are given. Before installation the main coupler and all hom couplers were tested in a single cell cavity up to a field level E_{acc} = 3.6 MV/m. The field was limited by a cavity quench in no relation with the couplers. Each cell has been equipped with r.f.-(antenna) probes. Their location slightly off-equator allows to couple to all modes.

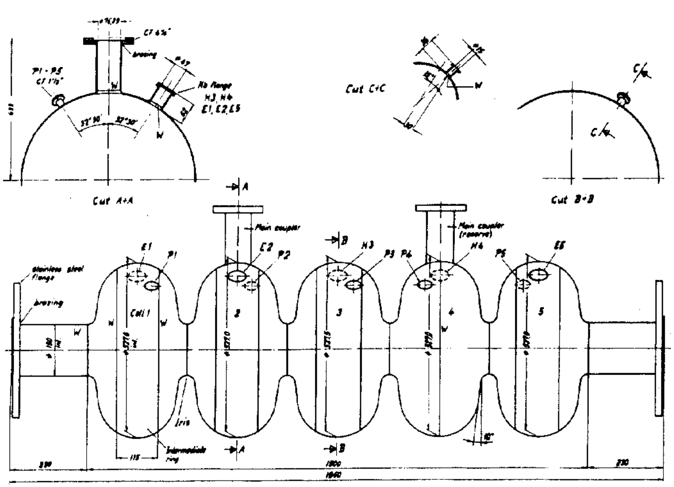

Fig. 1 Layout of 5-cell cavity; H3, H4: coupling ports for hom loop couplers; E1, E2, E5: coupling ports for hom antenna couplers; P1-P5: r.f.(antenna) probe ports.

TABLE 1 Some parameters of the 500 MHz 5-cell cavity

Design frequency (π-mode)	499.665 MHz
R/Q	665 Ohm
E_p/E_{acc}	2.05
H_p/E_{acc}	37.7 G/(MV/m)
Q_0 (Cu)	~ 47 000
Geometry factor	272 Ohm
Q_0 at 4.2 K (measured)	10^9
Cavity losses at 2 MV/m	14 Watt
Q_{ext} of main coupler	$5.5 \cdot 10^5$
Q_{ext} of hom couplers and RF probes for fundamental mode	> 10^{10}
$2(f_\pi - f_0)/(f_\pi + f_0)$	0.9%
Pressure dependence of frequency	-90 Hz/mbar
Tuning range	> 70 kHz

TABLE 2 Some measured higher order mode parameters for the 5-cell cavity

Mode		Frequency (MHz)	R/Q* (Ohm)	Q_{ext}** (10^3) Flat field distr.	Q_{ext}** (10^3) 27% detuned
	π	499.665	665	550	~ 570
TM_{010}	4π/5	499.207	< 1	800	2000
	3π/5	498.082	< 1	2900	1700
	2π/5	496.831	< 1	300	500
	π/5	495.694	< 1	400	800
TM_{011}	π	908.744	3	250	250
	4π/5	914.226	20	40	40
	3π/5	919.067	30	17	17
	2π/5	923.620	80	17	17
	π/5	924.674	120	16.3	16.3
TM_{110}	4π/5	732.178 731.737	25	365 75	290 55
	3π/5	736.855 736.593	50	83 87	85 90
	2π/5	740.376 739.724	15	300 140	160 80
TM_{111}	3π/5	1025.885 1026.507	15	60 25	60 25
	2π/5	1012.863 1014.085	120	120 100	120 100

* For flat field distribution; these values change only slightly with 27% field unflatness except for the TM_{010} - 4π/5 mode which increases to 25 Ohm. For the dipole modes the beam is assumed to be 5 cm off-axis.

** For the coupler arrangement shown in fig. 1.

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Each probe has been calibrated for the acceleration mode field amplitude during the cold test of the individual cells. The operation frequency of the acceleration mode was obtained by combining the results of single cell cold tests with Superfish[4] calculations for the 5-cell cavity. The cavity is mounted inside a support system which allows an individual frequency tuning of the 3 inner cells at room temperature (fig. 2). For the final tuning and for frequency regulation at PETRA, two motor driven mechanical systems allow to change the length of the two end-cells (fig. 2) independently.

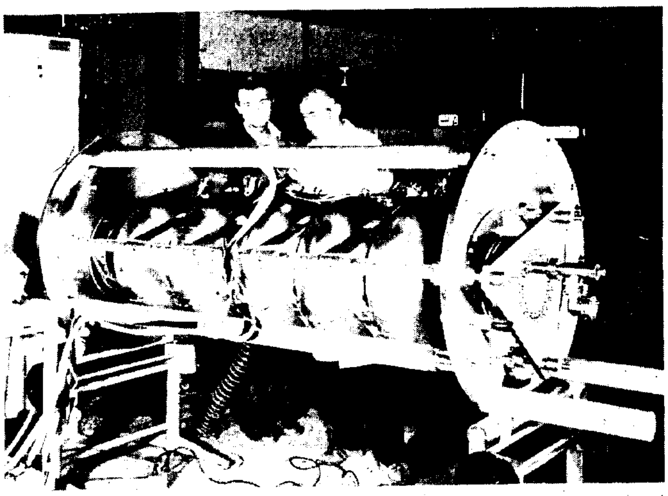

Fig. 2 Photography of the 5-cell cavity with its support and tuning system for the two end-cells. The outer support is used for handling the cavity. Some of the hom couplers and r.f.-probes are visible.

The cryostat

The cavity is mounted inside an horizontal LHe bath cryostat (fig. 3) leaving ample room around and at both ends of the cavity. The three inner cells with their couplers and r.f. probes remain fully accessible after insertion of the cavity into the He-tank. In order to reduce losses due to heat conduction and r.f. losses along the main coupler, the r.f. and control cables and along the beam tubes, counter flows of cold boil off He gas are used (typical gas flow rate: 0.1 g/s). The evaporation losses of the cryostat with all connections have been measured and amount to < 10 W. The cryostat can be used without major changes for operation with LHe dewars or with a refrigerator. For idling periods it can be kept cold by a LN_2 circuit.

Experimental results

The single cell cavities were tested individually before the final assembly. The results of these tests are presented in ref. 1. Accelerating fields above 5 MV/m were obtained at the first cooldown and the fields were always limited by a localised quench. The r.f.-losses were dominated by frozen-in magnetic flux (H_{ext} = 130 mOe) and the Q_0-values were $\gtrsim 10^9$.

For the assembly of the 5-cell cavity the 5 cells were welded together at the iris region (fig. 1) from outside. However, because of iris deformations and non-uniform wall thicknesses the initial welds were of poor quality and rewelding operations had to be done. These weldings were then reground and a (local) chemical polishing of ∿ 50 μm at the iris regions was applied.

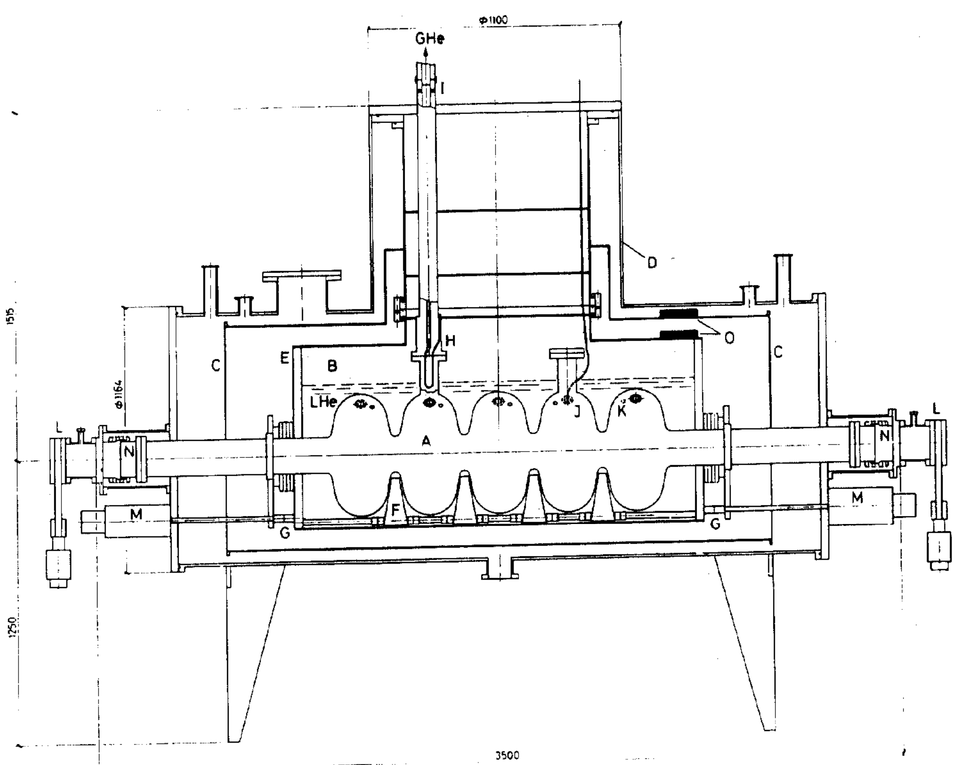

Fig. 3 Layout of the 5-cell cavity inside its cryostat. A: cavity, B: LHe-vessel welded to the covers E, C: cold shield, D: insulation vacuum vessel; F: support and tuning system for inner cells, G: tuner system for end- cells (1 low friction screw and 2 normal screws on each side), H: main coupler, I: coupler window; J: hom coupler with r.f. cable, K: r.f.-probe; L: beam tube valve, N: bellow, M: step motor for tuning system, O: supersinsulation.

In order to check these operations the cavity was measured in a vertical cryostat. For this measurement all hom couplers were mounted (but not the main coupler). After passing many multipactor levels a field E_{acc} = 2.7 MV/m was reached. At this field level no quench at the iris regions was observed and it was decided to stop the measurement to avoid a cavity degradation. Because of the relatively low Q_0 values ($Q_0 = 6 \cdot 10^8$) another rinsing with dust free water was applied before mounting the cavity inside the horizontal cryostat. During this mounting the cavity remained for 6 weeks under protective dust free gas (N_2). A leaky joint at the main coupler and a broken r.f. probe in cell 2 were replaced "in situ" by keeping the cavity under N_2 gas with a slight overpressure. The cavity was equipped with 40 resistors located around the irises, at the field enhancement regions of the couplers, at the location of the single cell breakdowns and at the bottom of each cell.

The main results of the cold test in the horizontal cryostat were: after tuning of the cavity to the design frequency a field flatness $(E_{max} - \bar{E})/\bar{E}$ = 5% was found. A thermal breakdown affecting a large part of cell 5 was detected at a field level E_{acc} = 2.1 MV/m. By detuning both end cells in opposite direction an asymmetric field distribution with a minimum field in cell 5 $(E_5 - \bar{E})/\bar{E}$ = -27% was established and a mean accelerating field E_{acc} = 2.8 MV/m was reached. At this field level a second thermal breakdown at the hom coupler region of cell 3 limited the field(*). As this breakdown occurred in the centre cell a further increase of the mean accelerating field by detuning was not possible. At the maximum fields in the flat and detuned arrangement no electron loading was present in the cells where the quench was observed. The quench field level could be raised by pulsing the RF at a reduced duty cycle. From these observations we conclude that the quench is of thermal origin. Contrary to the 4-cell multicell cavity very little non resonant electron loading was observed in the 5-cell cavity up to the field levels reached. As the coupler ports, however, distort the field configuration of the spherical cavities, we expected some electron multipacting. In fact, multipacting occurred in all single cells and in the 5-cell cavity at distinct field levels (1.4, 2.5, 3.0, 4.5 MV/m) which were within experimental errors the same for the different cavities tested. All levels could be processed away after a few hours of r.f. processing at the most. In the horizontal test the strong coupling of the main coupler made it particularly easy to pass these levels.

The Q_0-value at E_{acc} = 2 MV/m was determined by the evaporation rate of LHe. The boil off was then kept constant by substituting the r.f. losses by an electric heating inside the bath so that GHe flow conditions were not changed during the two measurements. By this method one cannot separate the contribution of coupler losses to the evaporation rate but it has been estimated from the measured temperature distributions that these contributions remain small. From the boil off (14 Watt) we estimate $Q_0 = 10^9$. The external Q of all hom couplers and r.f. probes for the fundamental mode lie well above 10^{10}. The external Q of the main coupler and of the arrangement of the 5 hom couplers have been measured and are listed in table 2 for all hom with R/Q values above 10 Ohm and with frequencies below ∿ 1500 MHz. It also was checked that a field unflatness of 27% does change the R/Q and Q_{ext} values only slightly with the exception of the $4\pi/5$ fundamental mode (table 2).

The tuner operation and regulation system were checked under various operating conditions. The smallest regulation step is 39.6 Hz i.e. ∿ 3% of the cavity 3 db-bandwidth B of 1 kHz. The tuning range obtained with one tuner system exceeds 70 kHz and is thus appropriate for detuning the cavity while idling inside the beam (separation of beam lines for single bunch operation of PETRA: 135 kHz).

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References

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2 E. Haebel, this conference.

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4 K. Halbach and R.F. Holsinger, Part. Acc. 7 (1976) 213.

(*) After these tests we got hints for water residues, produced accidentally during the last rinsing, causing these breakdowns in cell 3 and cell 5. Unfortunately the time schedule for installation in PETRA did not allow us to remove these defects.