

ELECTRO POLISHING AT DESY

N. Steinhau-Kuehl, T. Ebeling, K. Escherich, L. Lilje, A. Matheisen, H. Morales, B. Petersen
Deutsches Elektronen Synchrotron DESY, Hamburg, Notkestraße 85, 22602 Hamburg, Germany

Abstract

At DESY a facility for electro polishing (EP) of the superconducting (s.c.) TESLA/TTF cavities has been built. The EP infrastructure is capable to handle single - cell structures, the standard TTF nine - cell cavities as well as the proposed double nine - cell superstructure cavities. The goal of this facility is to increase the acceleration voltage of s.c. cavities reproducibly to the region of up to 40 MV/m. The E.P. process is computer controlled and there are 25 sensors monitored to control the process. The electro polishing facility is now operational since April 2003.

We report on measurements and experiences gained during the first electro polishing of single- and nine - cell cavities. We present specific data like heat production during the process, variation of current density and acid temperature. The results of the RF measurements of the first cavities treated in the new EP facility and the process parameters of those treatments will be shown. Another important point for reproducible results is the quality control of the electro polishing process. We will present a proposal of quality control steps to be implanted in the EP procedure.

INTRODUCTION

Since April of 2003 the EP for s.c. cavities at DESY is operational. The EP mixture in use is based on the one developed by Siemens company in the 70's and further developed by KEK in collaboration with Nomura Plating [1]. The EP acid is a mixture of 9 volume parts of sulphuric acid (96%) and 1 part fluoric acid (48%). For the EP process a temperature range of 30-40°C is chosen according to measurements done in 2001 [2]. The Cathode is made from pure aluminium. It is covered by a polymeric net to reduce contact between niobium and H₂. During the polishing process the cavity is orientated horizontally.

The commissioning of the EP facility was made on four single - cell cavities from which three have undergone an RF measurement at 2K. Three nine - cell cavities are actually in the EP preparation sequence.

The parameters sets for single- and multi cell cavities are well studied at CERN and KEK [3]. These studies serve as basic parameters for our EP process.

ELECTRO POLISHING FACILITY

Infrastructure

The EP facility was built up next to the TTF clean room with the advantage of very short ways between the EP facility and the high pressure rinsing facility at the end of the EP process (see Fig.1).

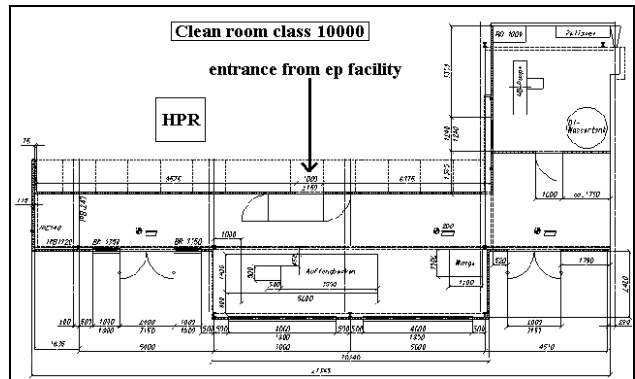


Fig.1: Ground plan of the E.P. facility.

To reach a high level of personal safety and a very low influence on the acid due to contamination of the acid system, a closed loop acid circuit was designed (see Fig. 2).

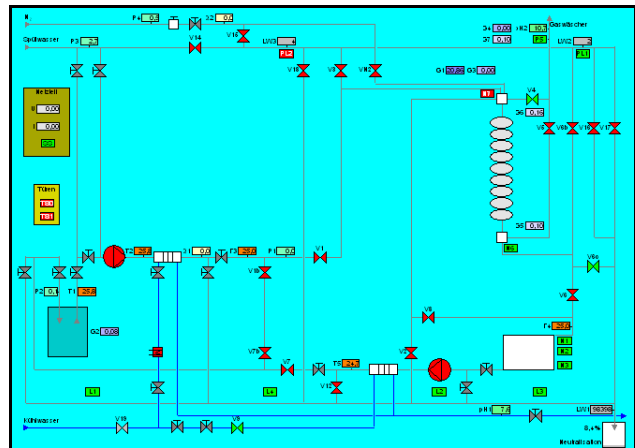
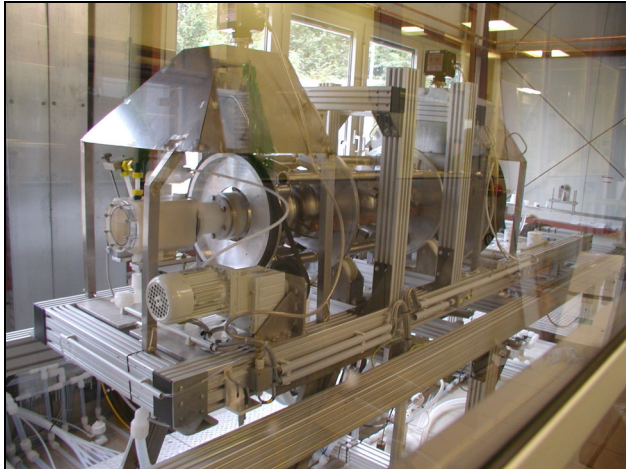


Fig. 2: Flow chart of the E.P. facility.

The cavity is mounted on a bench (see Pic.1) in vertical position. After starting the computerized process the cavity is put to the horizontal position for the EP process. More than 30 different sensors are installed to control the polishing process. 25 of them are monitored and visualized continuously by the process computer [4] to

control the parameter set (see Fig. 2). If one or more of these parameters run out of the programmed limitation the EP facility will automatically send out an alarm and return into a secure state. The monitored signals and a list of the error messages are handed to the operator who can analyze the data and decide later how to continue, while the system is in a secure position.



Picture 1: 9 cell cavity installed on the EP bench.

Another important point is that the complete parameter set is archived and can be used later, i.e. compare different current curves for analyses of the process and comparison of different treatments and cavity results.

The Variation of Temperature and Current Density

In electrolytic solutions the electrical conductivity of the solution is proportional to the temperature [5]. This means that for a constant voltage the current is only depending on the temperature and the size of surface in contact with the solution (see Fig. 3). The DESY EP feeding heads limit the acid level to a level at which 53 % of the cavity surface is covered by acid.

If the temperature during the EP process is not stabilized by a heat exchanger, the heat production will cause a process temperature above 40°C after a while. Acid temperatures above 40°C are problematic because PVDF gets unsuitable at higher temperatures.

ELECTRO POLISHING OFF SINGLE - CELL CAVITIES

All single - cell cavities were electro polished with no heat exchanger installed in the system. The disconnection of the heat exchangers was necessary because the first commercial version was not leak tight against hydro fluoric acid.

Process Parameters

From April'03 to June'03 four different single - cell cavities were electro polished to commission the EP system at DESY (see Tab. 1).

cavity	date	temp. start	temp. end	current start	current end	acid flow rate
1B8	08.04.03	17,4	23	37	53	4,7
1S2	22.05.03	22,7	25,6	37	54	6,4
1B12	04.06.03	26,7	31,8	51	69	5,8
1B12	05.06.03	26,3	32,3	53	70	5,7
1AC2	17.06.03	25	28,9	50	63	6

Tab. 1: process parameters of the single - cell cavity treatments.

For the single - cell treatments a constant voltage (18 V) was applied and the process duration was limited to 60 min, respectively a temperature limit of the acid of 35 C . Due to the absence of the heat exchangers the different start temperatures are related to changing ambient temperatures. The values of "Current start" and "current end" are average values of the current oscillation recorded.

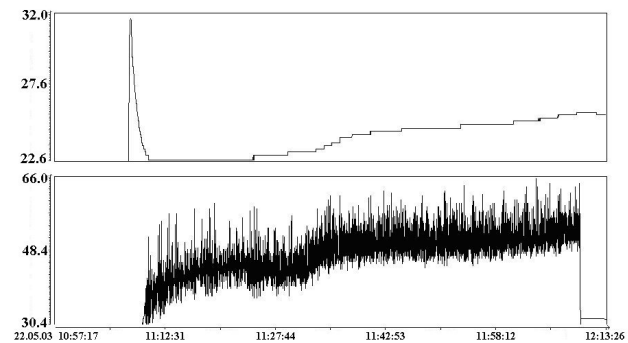


Fig. 3: upper graph: T-t [°C-real time]
lower graph: I-t [A-real time].

Results of the Single-Cell Cavities RF Measurements

The results of the RF measurements (after baking at 138C) of the first single - cell cavities treated in the new EP facility at DESY are shown in Tab. 2.

cavity	Eacc [MV/m] lmb	Eacc [MV/m]	Eacc[MV/m] a. baking
1B8	28,2 (2K)	32,4 (2K)	37,9 (2K)
1S2	31,2 (2K)	31,2 (2K)	41,6 (1,8K)
1AC2	34,8 (2K)	30,9 (2K)	38,4 (2K)

Tab. 2: Results (lmb = last measurement before EP).

The single - cell cavity 1B12 was not measured in a RF-test because of an accident during high pressure rinsing. The results of the cavity tests show that all cavities recovered from former problems after EP processing in the new infrastructure. The DESY EP facility is now qualified for high gradient cavity preparations.

ELECTRO POLISHING OFF NINE - CELL CAVITIES

Until today three nine - cell cavities were electro polished at DESY. For the nine - cell cavity treatments a heat exchanger in the acid return pipe is in use. It is capable to stabilize the temperature of the storage barrel and extend the processing time up to several hours.

Results of the Nine-Cell Cavities RF Measurements

The nine - cell cavity AC 78 has had an accident during preparation of He vessel welding prior a horizontal test. Due to this accident the cavity performance degraded from 35 MV/m to 15 MV/m and was limited by heavy field emission. For this cavity an EP of 90 minutes, which means a total removed niobium of 30-40 μm, was applied to remove the defect.

cavity	Eacc [MV/m] lmb	Eacc [MV/m]	Eacc[MV/m] a. baking
AC78	15,3 (2K)	-	23,7 (2,1K)

Tab. 3: cw test results of the first nine - cell cavity (lmb = last measurement before EP).

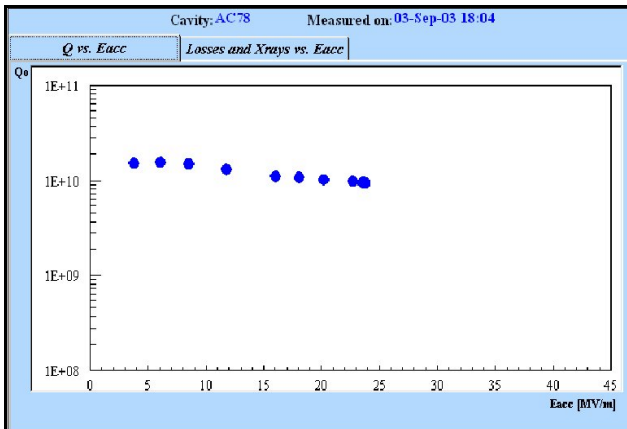


Fig. 4: Q vs. Eacc curve of AC78 (limitation: quench).

As shown in Tab. 3 and Fig. 4 the cavity AC78 improved in performance in respect to the last measurement by applying the DESY EP. The cavity reached 23,7 MV/m at a Q of 1 Exp 10 at 2,1 K. It was limited by a quench and showed no field emission, which can be interpreted as insufficient material removal to fully cure the cavity from the defect. Another 90 min EP will be applied.

Heat Production

For the computation of the heat production during the EP process we assume a specific thermal capacity c_p for the acid mixture of 1,42 kJ/(kg K) [6]. ΔT is defined as the difference of the temperature T3 measured at the entry of the acid into the cavity and the temperature T4

measured at the acid exit tubes. To calculate the heat production we used the following formula:

$$P = c_p * \delta_{H_2SO_4} * \Delta T * \dot{V} \quad (1)$$

The data recorded during processing of the cavity P-1 are shown in Fig.5.

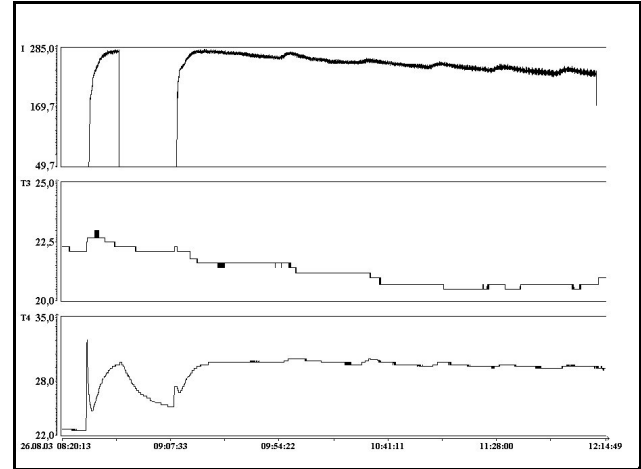


Fig. 5: Data record of the EP treatment on cavity P-1 (Top: current [A] / middle: Temperature T3, acid entry [C]/bottom: Temperature T4, acid exit [C]).

Particularly remarkable is the comparison between the development of the electrical power and the heat production. The heat production is nearly stable during the process while the electrical power slowly decreases (see Fig. 6).

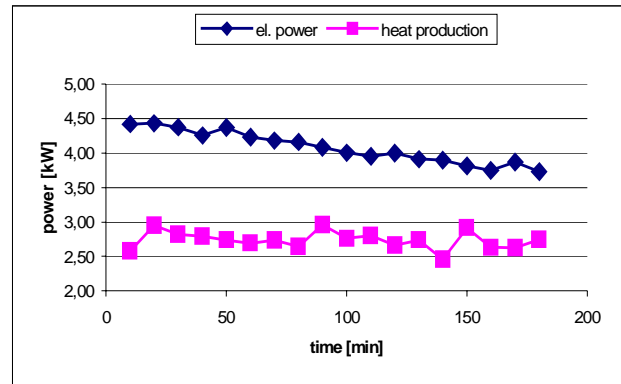


Fig. 6: electrical power and heat production of P-1 treatment.

OBSERVATIONS

During the three EP procedures done on the 9 cell structures with the same barrel of acid in use, we made two observations about the behavior of the EP acid mixture.

Relation of Surface Size, Activity of the Acid and Current

The slow decrease of the electrical power with constant heat production (see Fig. 6) may probably have two causes.

a) Assuming that the current is correlated to the temperature gradient ΔT , voltage V , the surface area A and the activity of the acid a ,

$$I = f(\Delta T, U, A, a) \quad (2)$$

and further more that $T, U = \text{const.}$, then there is a relationship that we call adapted current.

$$\frac{I}{\Delta T * U} = f(A, a) \quad (3)$$

b) During the EP process the surface becomes smoother and in parallel the activity of the acid is reduced through the chemical process (increasing amount of dissolved niobium and decreasing amount of free HF).

If we use the function for the adapted current (see Eq. 3) and plot the date of the three processes A14; AC 78 and P-1, done at nearly similar temperatures, in an time depending sequence, we get the graph shown in Fig 7. In this graph both effects, smoothening and aging of acid are evinced.

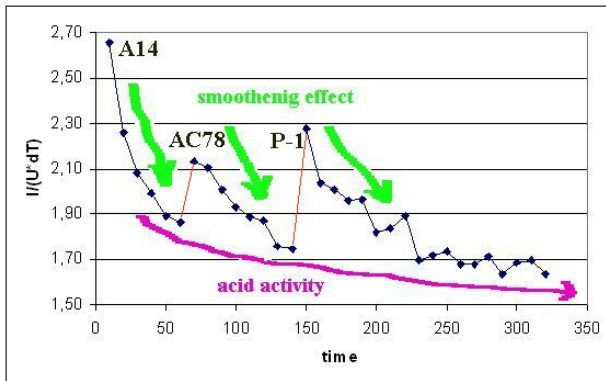


Fig. 7: Adapted current (a) versus acid in use time of three EP test sequences.

The lower envelope in Fig. 7 represents the aging of the acid while the enhanced activity at the beginning of each process represents the larger surface due to the roughness of the Niobium. To support this observation still more EP treatments are needed.

EP With Other Parameter Sets?

During the first single - cell treatment on 1B8 the process conditions were not within the optimal parameter range of 30 to 35 °C [Ref. 2]. Compared to this values the temperature was to low (17,4°C – 23,0°C). Due to the commissioning sequences of the infrastructure, the acid was diluted with water (density = 1,77 g/l) and there was no current oscillation observed on the 1B8 treatment (see

Fig. 8) as it was in other treatments (see Fig. 9). Nevertheless the RF measurement shows, that the cavity was well polished (see Tab. 2) and reached similar results like measured for 1AC2 where the current oscillation during the treatment was established.

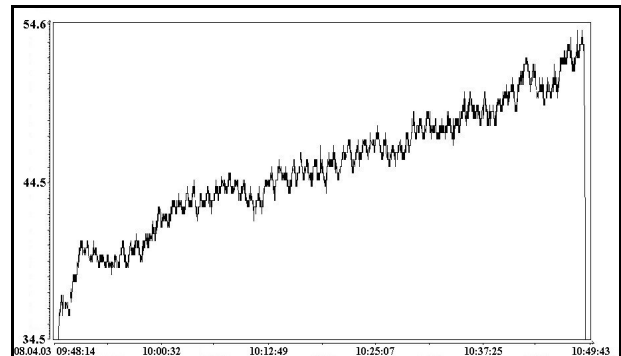


Fig. 8: current curve of 1B8 without current oscillation.

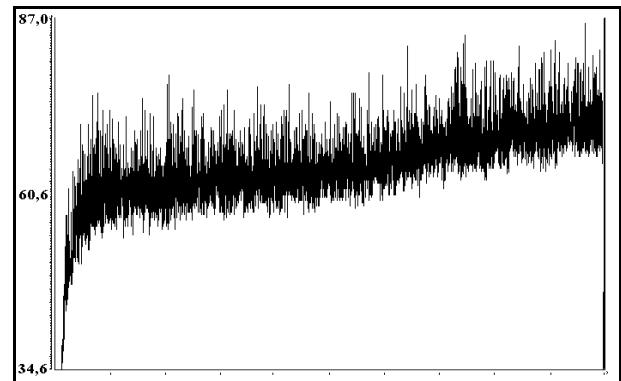


Fig. 9: Current curve of 1AC2 with current oscillation.

PROPOSAL FOR THE QUALITY CONTROL OF THE ACID

We decided to record two parameters of the acid before every EP treatment. The first parameter is the density of the acid which shows how diluted the acid is (with water). The second parameter is the quality of the acid, which can be shown with a polarogram. In addition attempts are made to study the validity of samples installed in the cavity. Parameters like shininess, roughness and removal rate may give more information's on the process before the rf measurements in order to have an insito information of the process.

ACKNOWLEDGEMENTS

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