Update on the Experiences of Electropolishing of Multi-Cell Resonators at DESY

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Abstract

At DESY electro-polishing (EP) is applied on super-conducting cavities for about 2 years now. Acceleration gradients of up to 39 MV/m have been achieved on 1,3Ghz nine cell resonators. The EP infrastructure is running continuously since 2004 and serves as major surface preparation tool now. Data, based on the statistic gained so far, are available for parameters like current density, removal rate, live time of components and process temperature. We report on the latest data as well as on ongoing studies on material stability and sulphur segregation that was found recently during maintenance of the EP infrastructure.

INTRODUCTION

During the last production series new steering parameters were found to stabilize the EP process. We report on the latest changing's, results of the last cavity production series and the problem of field emission.

CHANGE OF THE CONTROL PARAMETER

To keep the current as stable as possible the temperature inside the cavity should be held constant. This temperature is chosen to be 30°C. The basic layout of the DESY EP facility had foreseen two heat exchangers of nominal 20 KW heat exchange capacity each to stabilize the temperature. The commercial heat exchanges failed [Ref.1], a manual steering of a single heat exchanger installed in the acid feed back (AFB) line (Fig. 1) is applied. The first EP treatments were steered in respect to T4 to keep the cavity outlet temperature constant. This method did not give very stable conditions because T4 is affected by the current and the long time constant acid circuit. The heat capacity of the acid inside the storage vessel leads to a strong buffering and slow reaction on the Temperature (stored volume 150 l / acid exchange rate 10-12 l/min).

Changes on the heat exchange rate in the AFB line appear with a time delay of about 4 Min. From measurements done on sample [Ref. 2] it is well known that the current of the voltage stabilized EP is strongly depending on the temperature. The new method for temperature stabilization is to stabilize the temperature inside the storage barrel (T1). The steering parameter is more efficient because the temperature of the feed in acid will effects the current directly (see Fig.2) and the buffering behavior of the stored acid stabilizes the process in addition.

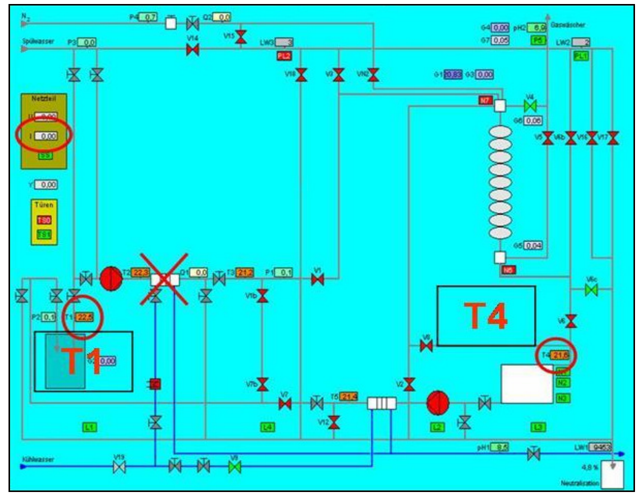

Fig. 1: Schematic Plan of the EP facility

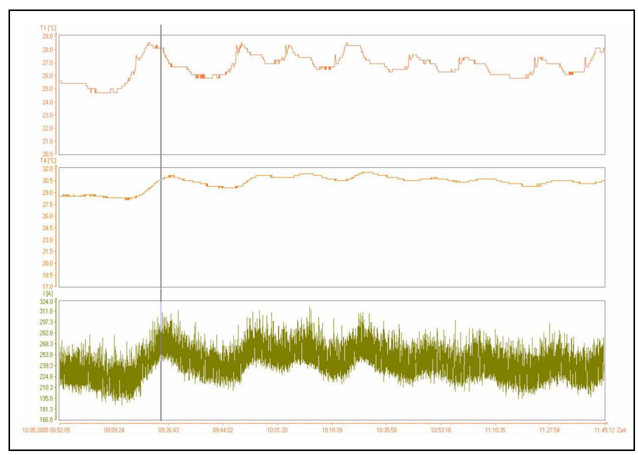

Fig. 2: Temporal connection between T1, T4 and I

Consequences from the new control parameter

As a result of new control parameter the current during the processing time appears much more stable (Fig. 3). Actual analysis of the cavity test results show that at process temperatures of 30 to 35 C the cavities reach higher gradients [Ref. 3].

The absence of an inline heat exchanger in the acid feed line does not allow pre-heating of the acid when the EP process is started. Typical start temperatures of the DESY EP are 20 to 23 C. With typical currents of 250 A at 17 V the acid temperature inside the barrel reaches 26° C in about 20 MIN. At T1 = 26° C the heat exchanger is switched to 50 % exchange capacity and at T1 = 27° C it is set to full capacity. By this new method typical currents of 300 A of the DESY EP nine cells treatments can be stabilized within ± 20 A.

The industrial heat exchangers installed at the DESY EP did not fulfill the needs to stabilize the process. Safety regulations for the DESY EP do not allow to store more than 240 Kg of acid and to install a separate acid fill station like realized in the DESY BCP circuit [Ref. 3]. The acid temperature stabilization by an integrated heat exchanger inside the storage barrel can not be realized at the DESY EP. A new type of heat-exchanger, made from pure alumina, is under construction and test.

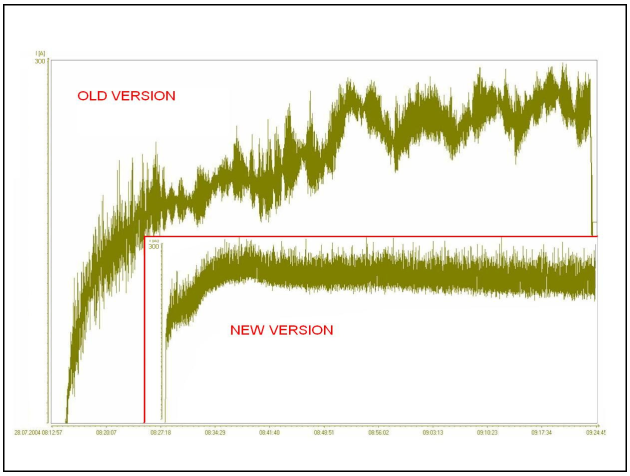

Fig. 3: Stability - comparison of the two parameter sets

RESULTS OF CAVITY RF MEASUREMENT

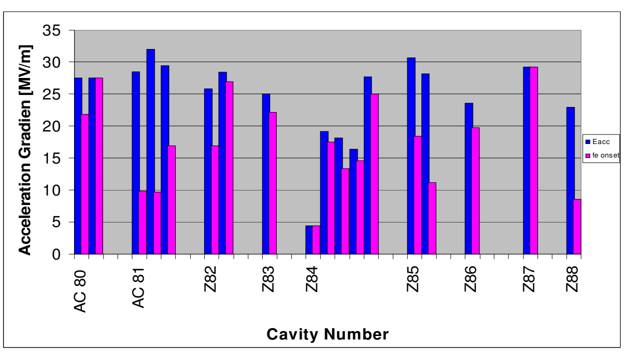

Fig. 4: Cavity Measurements and fe-onset before baking

The EP treatments of the latest cavity production started in August 2004. For these cavities only EP was applied to remove damage layer and for final preparation for vertical test [Ref. 4] as well. No post purification by Titanium getter like done for the previous BCP treatments is applied. Nine resonators have been polished since. Some of them have undergone the EP treatment several times. The RF test results are shown in Fig. 4-5, Tab. 1-2.

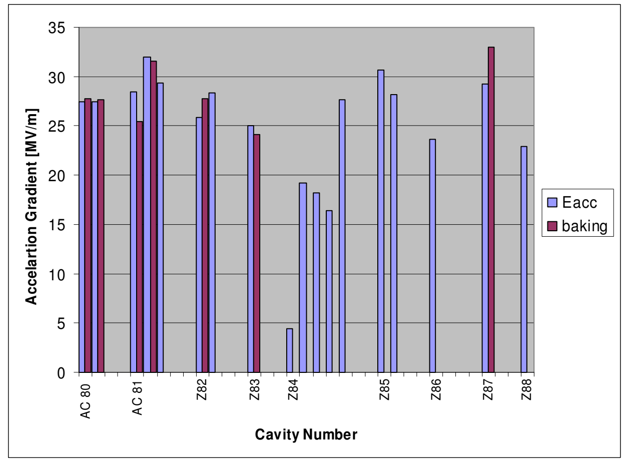

Fig. 5: Cavity measurements before and after baking

	before baking				[MV/m] in cells				
	Eacc [MV/m]	fe onset [MV/m]	Limit.	Origin	1/9	2/8	3/7	4/6	5
AC 80	27,50	21,80	bd	Q+ QD					
	27,50	27,50	bd	Qnd	37	34	37	38	33
AC 81	28,50	9,87	bd	Q+fe					
	32,00	9,70	pwr	Qdhf					
	29,38	16,90	bd	Qnd	29	35	30	40	31
Z82	25,80	16,90	bd	Q					
	28,90	26,90	bd	Q	26	38	29	35	39
Z83	25,00	22,20	bd	Q	29	34	36	27	36
Z84	4,41	4,41	pwr	QD					
	19,20	17,50	pwr	QD					
	18,20	13,30	pwr	RFC					
	16,40	14,60	pwr	QD					
	27,70	25,00	bd	Q	32	33	38	41	43
Z85	30,70	18,45	pwr	fe	41	40	38	37	41
	28,20	11,20	pwr	RFC					
Z86	24,00	19,75	bd	Qnd	29	32	32	32	34
Z87	29,50	29,50	pwr	Qdhf	36	33	34	38	40
Z88	22,90	8,60	bd	Q+ fe	27	31	27	34	36

Tab. 1: Results Of Cavity Measurements before baking (Q=Quench, QD=Q Disease, Qnd= Quench location not detected, fe=field emission, Qdhf=Q drop at high field, bd=break down, pwr=power, RFC=RF cable)

The resonators Z82-Z84 are limited at the equator welds due to a production error. Not taking these resonators in to the statistic, the average acceleration gradient of cavities tested so far is 28 MV/m before baking at 120 C while the cell statistic (Tab.1 and 2) show an average gradient 35 MV/m. The resonator gradient spread in gradients in the acceleration mode reaches from 24 MV/m to 32 MV/m before baking, respectively from 27 to 33 MV/m after baking.

The actual existing correlation of material removal and acceleration gradients is shown in (Fig. 6). From these limited data there is intuitively no strong correlation to be seen. The wide range of the gradient spread as well as the not existing correlation of gradient and removal may be

After baking					gradient in cell [MV/m]				
	Eacc [MV/m]	fe onset [MV/m]	limitation	Origin	1/ 9	2/8	3/7	4/6	5
AC80	27,80	24,00							
	27,70	27,70	bd		31	35	33	41	29
AC81	25,40	13,20	pwr	fe					
	31,55	22,90	bd	Qnd					
	---	---							
Z82	27,80	25,90	bd	Q	28	41	31	36	41
	---	---							
Z83	24,10	24,10	bd	Q					
Z84	---	---							
	---	---							
	---	---							
	---	---							
	---	---							
Z85	---	---							
	---	---							
Z86	---	---							
Z87	33,00	33,00	bd	Qnd	41	35	40	40	44
Z88	---	---							

Tab. 2: Results Of Cavity Measurements after baking

explained by the strong field-emission loading of the cavity (Fig. 6). More investigations by temperature mapping have to be applied to understand the wide spread.

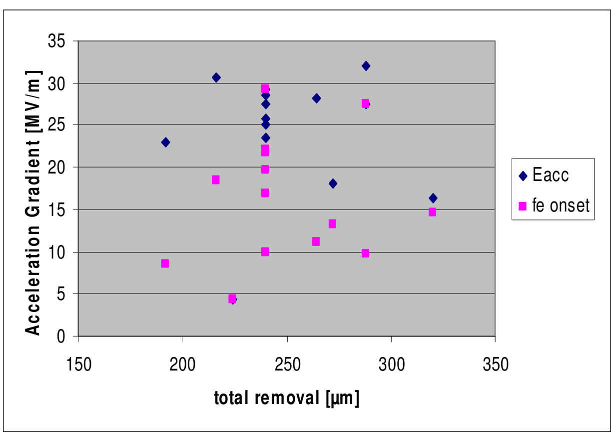

Fig. 6: Acceleration gradient (Eacc) and field emission onset gradient (Eacc. Feonset) plotted in respect to the total removal of Niobium by electro-polishing

FIELD EMISSION

The main limitation of the electro polished cavities seems to be the field emission. After EP most cavities show a field emission onset between 15 and 20 MV/m. Origins of field emission are mechanical defects like scratches or holes, chemical residues, or dust on the superconducting surface in the iris region.

Sulfur

During the EP process crystalline sulphur segregates out of the acid [Ref. 5]. After a few hours a thin film of sulphur was found on tubing surface. Sulfur is water insoluble, and it can not to be excluded that the sulfur is also on the cavity surface after the HPR. There is the possibility that sulfur crystals on the niobium surface can produce field missions. To remove this sulfur we are planning to rinse the cavity with ethanol. The solubility of sulfur in ethanol at 20°C amounts to 1,14g S / 100g C_2H_5OH. A small test shows that it's possible to remove the sulphur layer (after 50h) with ethanol (Fig.7).

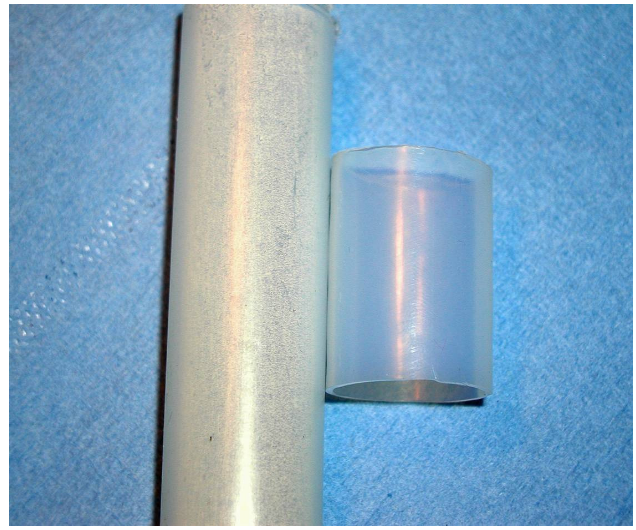

Fig. 7: Tube with sulfur layer and after ethanol cleaning

CONCLUSION

A new steering parameter for temperature stabilization is introduced in the DESY EP. This parameter helps to overcome the problems of temperature stabilization due to the failure of industrial heat exchangers. A wide spread of cavity acceleration gradients is observed. Correlations of the EP plant parameter do not give information on the origin of this spread. Strong field emission loading of the resonators and sulfur sedimentations in the DESY EP apparatus are observed. A correlation of these two findings has to be studied by temperature measurements and cavity rinsing with alcohol to ensure the removal of sulfur from the cavity surface.

ACKNOWLEDGMENTS

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