Developments in conditioning procedures for the TTF-III power couplers

H. Jenhani, T. Garvey, P. Lepercq, M. Omeich, C. Prevost, A. Variola

DEVELOPMENTS IN CONDITIONING PROCEDURES FOR THE TTF-III POWER COUPLERS*

H. Jenhani#, T. Garvey, P. Lepercq, M. Omeich, C. Prevost, A. Variola, Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B.P. 34, 91898 Orsay Cedex, France.

Abstract

Despite extensive experience in many laboratories on power conditioning of couplers for RF superconducting accelerators, it is still not a well understood procedure and can produce many unpredictable phenomena. There remains considerable interest in reducing the power coupler conditioning time necessary for superconducting linear accelerators. This paper presents studies of optimisation of the conditioning procedure for the couplers intended for use on the European XFEL project.

INTRODUCTION

The Laboratoire de l'Accélérateur Linéaire (LAL) has the task of preparation and conditioning of thirty TTF-III couplers for the superconducting linear accelerator project, FLASH, at DESY. These couplers will be mounted on the cryo-modules of the FLASH linac and their operation will provide valuable experience for the European XFEL project. The latter will use almost 1,000 couplers of the TTF-III type. Such couplers are also the baseline choice for the International Linear Collider (ILC) which would require between 10,000 and 20,000 units. For projects which require couplers in such large numbers, conditioning becomes an important consideration in terms of time and cost. As the couplers themselves are complex RF elements, for which multiple mechanical fabrication techniques are used, one may find variations between the finished objects. This may lead to varying conditioning times from one coupler to another. We will present the results of our conditioning experience with the TTF-III couplers and discuss changes in the conditioning procedure aimed at reducing the processing time needed while operating in a safe and reliable fashion in order to protect the coupler.

TTF-III CONDITIONING PROCEDURE

TTF-III couplers are conditioned in pairs assembled together to a wave-guide test box via their cold parts. As each coupler has two ceramic windows, this assembly has three independent vacuum chambers; one on the input of each coupler (the warm part) and a common one (the cold parts). The assembly and conditioning procedure is described in reference [1]. It is essentially based on vacuum level / RF power monitoring. At the start short, 20 μs, RF power pulses are used. As long as the measured vacuum levels are lower than a first threshold of $2x10^{-7}$ mbar, the power is increased in steps to a maximum level. When this is reached the power is then reduced to a minimum value and then ramped up in the same way as before but with lager pulse widths (Fig. 1). Any increase of vacuum above this threshold results in a power reduction. If the pressure in any part of the coupler assembly exceeds a second threshold of $4x10^{-7}$ mbar, the power is decreased more drastically. For vacuum events exceeding 10^{-6} mbar, hardware interlocks cut the power immediately. Without these protective measures electron (e^-) currents created by electro-magnetic (EM) effects on surfaces could generate severe discharges which may be particularly harmful to the couplers. Therefore, electron current interlocks are also used to limit the current build-up.

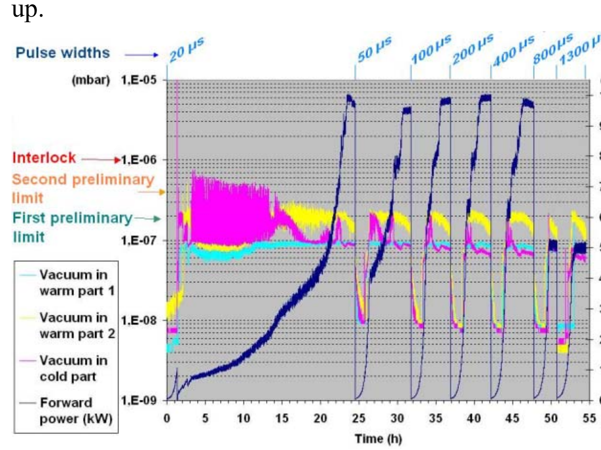

Figure 1: Forward power monitoring based on vacuum levels.

The choice of the vacuum thresholds and the interlock limit values is a compromise between establishing a safe procedure and avoiding lengthy conditioning. Optimising these choices may allow a substantial gain in conditioning time.

OVERVIEW OF TTF-III COUPLER CONDITIONING AT LAL

The first step of the coupler conditioning activities at LAL was to apply the DESY procedure with respect to preparation, cleaning and secure operation. Conditioning results were very satisfying in terms of coupler handling, conditioning time and conditioned coupler performance [2]. Some of these conditioned couplers were tested on TESLA cavities in the CHECHIA horizontal cryostat at DESY where they successfully allowed 35 MV/m cavity gradients to be achieved [2]. Our second aim was to

*We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).
Corresponding author: jenhani@lal.in2p3.fr

optimise the conditioning procedure by analysing the behaviour of the couplers during their conditioning.

First we studied the influence of in-situ baking on the coupler conditioning time. We wished to determine if one could obtain, through "lengthy" conditioning, equally low vacuum levels for an un-baked coupler as those obtained when using in-situ baking. We found that baking allows one to reduce the conditioning time by almost a factor of two. Furthermore it provides better vacuum levels in couplers prior to conditioning than those obtained at the end of fully conditioned, non in-situ baked, couplers [3].

Afterwards we tried to reduce the conditioning time by changing the vacuum security levels and the control timing parameters. These actions may produce unpredictably strong events such as discharges in the coupler during conditioning. This is due to the strong influence of the vacuum levels on couplers subject to strong EM fields.

VACUUM THRESHOLDS AND CONDITIONING TIME

In-situ baked TTF-III couplers at LAL show a spread in conditioning time from ~ 45 to ~ 90 hours with an average of about 60 hours (Fig. 4). Examining the best times obtained at LAL and DESY, 45 hours seems to be a reasonable limit to the conditioning time for the existing test facility and procedure. To do better, we have to make some changes to the procedure. The study of the behaviour of these couplers during conditioning showed that many hours of the conditioning were not efficient for the process.

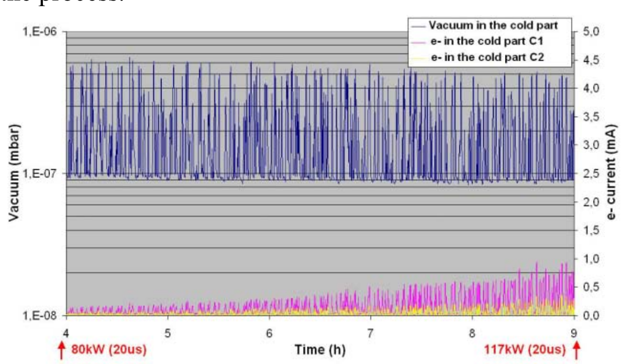

Figure 2: Example of high vacuum level variations without a real conditioning effect. C1 and C2 denote couplers 1 and 2 respectively.

As we can see from Figure 2, there were periods during which the conditioning progress was blocked by continuous vacuum level variations in the absence of significant e^- current signals. Conditioning is essentially based on a reduction of the secondary emission coefficient of the coupler surfaces under electron bombardment [4]. In this, typical, example we can see that 5 hours were needed to raise the power from 80 kW to 117 kW. We can also see that, had we used 6×10^{-7} mbar (3 times the value used) as a first threshold, it would have allowed us to avoid this conditioning stage.

To have a concrete idea about the possibility of changing this crucial parameter without causing any harm to couplers we have calculated the effective pumping speed for each vacuum part of the coupler assembly. An estimate of the ratio of the real to measured vacuum values was also computed. The same calculation was made for the pumping arrangement of the DESY test stand. The comparison between the two arrangements is summarised in Table 1. According to these numbers, it appears that we can increase all our vacuum limits by a factor of five without taking a major risk. The new chosen values for the first and second thresholds and the vacuum interlock limits were 6×10^{-7}, 1×10^{-6} and 5×10^{-6} mbar respectively.

Table 1: Comparison of the LAL and DESY pumping arrangements.

		LAL	DESY
Ion pumping speed at the vacuum port		20 l/s	60 l/s
Warm part coupler 1	Effective pumping speed	11.4 l/s	7.1 l/s
	Real pressure /measured pressure	1.47	8.5
Warm part coupler 2	Effective pumping speed	11.4 l/s	5.0 l/s
	Real pressure /measured pressure	1.47	12
Cold part	Effective pumping speed	7.78	5.0
	Real pressure /measured pressure	2.15	12

The first conditioned tests made with these new parameters were a success. The conditioning time of the processed couplers was about 24 hours which is almost half of our previous best time (Fig. 4).

REDUCING THE CONDITIONING TIME BY CHANGING THE PROCEDURE SPEED

The analysis of the progress of this conditioning test revealed that those steps using pulse widths larger than 20 μs required hardly any more time than that needed by the monitoring and control program to increase the RF power to its maximum value. This is because the measured pressures were always below the new threshold values. Apparently, increasing the power-control loop speed will save a few hours of the time execution of these steps. However, we do not know the effect of this change on the 20 μs pulse conditioning which is by far the most time consuming step. To make this new change on the conditioning procedure we adopted the following criteria to chose the new delay time for the power-control loop, which had previously been thirty seconds: The pumping system should have enough time to pump a pressure rise near to the vacuum interlock limit (5×10^{-6} mbar) down to less than the first threshold value (6x10^{-7} mbar) during only one delay time of the loop, if the event causing this vacuum burst vanishes.

To have a realistic estimation of the recovery time of our pumping system, we studied the pumping reaction following interlock events on several coupler conditioning tests. This gives many examples of the vacuum recovery time after a significant pressure burst.

Figure 3: Examples of vacuum recovery after an interlock event.

As we can see from these examples, concerning vacuum variation in warm and cold parts, 5 seconds can be sufficient to pump down the pressure from 5x10^{-6} to 6x10^{-7} mbar. To have a security margin we decide to take three times this value as a new loop time delay.

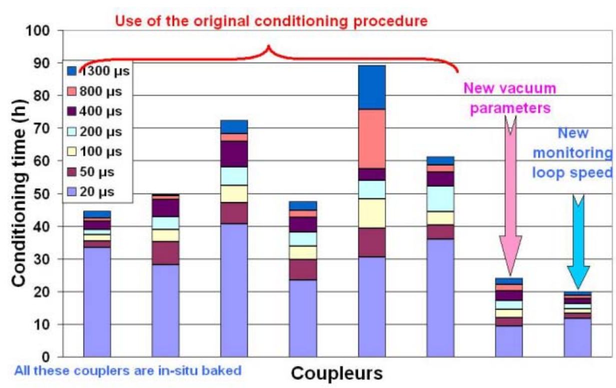

Figure 4: The new TTF-III conditioning time performances at LAL.

The conditioning time with this last parameter change was about 20 hours (Fig. 4). All the gain in time was saved from those steps with pulse widths larger than 20 µs.

REMARKS

By using the new conditioning parameters, processing seems to progress with no great difficulties once the 20 µs step is over. We also noticed that this step was more time consuming for the 15 s delay time loop conditioning than for the 30 s case. This appears to be linked to a new problem that we faced with these two parameter changes. In these last conditioning tests, many e^- current interlocks were activated which were not seen for the original parameters. A meticulous observation of these new events shows no correlated vacuum burst as is usually observed in electrical discharge events. Moreover the e- current values just before the interlock activation are slightly inferior to the chosen interlock limit value. Consequently, we presume that these interlocks are not due to a discharge event but to a "soft" e^- current excess of the tolerated limit. These new kind of events have been observed only recently because the conditioning procedure progress has become too rapid to reduce the secondary electron emission enough before reaching high electron current levels for the coupler. Conditioning with the reduced control loop delay time showed more of these type of interlocks than the prior conditionings. The additional time required to perform the 20 µs stage is essentially equal to the time lost through these additional interlocks. Relaxing the e^- current interlock limit may slightly reduce these conditioning times and also any influence that coupler manufacturing differences may have on the spread in measured conditioning times, such as has been observed with the non-optimised procedure tests (Fig. 4). Raising the RF pulse repetition rate is also another option to enhance the surfaces conditioning effect in order to reduce the e^- current more efficiently.

CONCLUSION

Some optimisation of the use of the TTF-III conditioning procedure has been attempted at LAL-Orsay. New conditioning time performances were a factor of two faster than our previous best results. The results are promising but some other modifications of the procedure, such as changing the e^- current interlocks limit or an increase of the power pulse repetition rate remain to be studied.

More conditioning statistics on these new parameters are needed to confirm the possibility of reducing the dependence of conditioning time on manufacturing differences.

ACKNOWLEDGMENTS

The authors thank T. Chabaud, L. Grandsire, B. Mercier and A. Thiebault for their contributions to this work.

REFERENCES

[1] B. Dwersteg, D. Kostin, W.-D. Möller, "TESLA RF power couplers development at DESY", Proceedings of the SRF2001 Workshop, Tsukuba (Japan).

[2] D. Kostin, Presentation "Power Coupler: Testing", EIFast-Workshop on the European X-FEL Project, DESY, Hamburg, Germany, May 2006.

[3] H. Jenhani, "Preparation and Conditioning of the TTF VUV-FEL Power Couplers", Proceedings of the SRF2005 Workshop, Ithaca, New York,USA.

[4] B. Henrist et al., « The Variation of The Secondary Electron Yield and of the Desorption Yield of Copper under Electron Bombardment : Origin and Impact on the Conditioning of LHC », EPAC, France, 2002.