LAST SPIRAL 2 COUPLERS PREPARATION AND RF CONDITIONING

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Abstract

After some field emission problems in the Spiral 2 cryomodules, a control of the number of particles measured was added for each component mounted in the LINAC, including the power couplers.

We present here the evolution of the coupler protocols to achieve the cleanliness specification. We also show the results and conclusions.

INTRODUCTION

The Spiral 2 facility [1] is under construction at GANIL (FRANCE). SPIRAL 2 is based on a 40 MeV, 5 mA deuteron and a 14.5 MeV/u - 1mA heavy ion superconducting accelerator.

Its LINAC operates at 88.05 MHz. It is composed of 12 cryomodules with one low beta (0.07) cavity per cryomodule and 7 cryomodules with two high beta (0.12) cavities per cryomodule. The cavities reach a nominal accelerating gradient of 6.5 MV/m.

Both types of cavities are equipped with the same coupler. Each family of cavity has its own coupling factor; the difference is achieved by changing the length of the outer conductor. The RF power couplers [2] provide up to 12 kW CW beam loading power to each cavity and they were validated up to 40 kW CW in travelling wave [3].

In 2010-2011, the tests of the first three assembled cryomodules B showed high radiation dose rates (> 100 mSv/h) leading to quenches below the nominal field of 6.5MV/m. The source of this field emission was dust pollution during the preparation of the components [4].

To address this issue, in 2012 for each piece mounted in each cryomodule, a control of the number of particles measured was added when blowing with N2 filtered at 5 bars. The cleanliness specifications imposes:

- particle ≥ 5 µm : none.
- particle < 0.5 µm : less than 100 particles per 28 liters.

Since this specification was imposed, all cryomodules, A and B, have been tested successfully (RF, vacuum, cryogenic).

Thanks to our experience, we have optimised the protocol for the RF conditioning of the couplers at LPSC (France) and so we are now saving a lot of time.

We present here the coupler protocols evolution. We also show the results obtained before and after the changes and the conclusions obtained.

COUPLER PROTOCOLS EVOLUTION

Preparation protocol

The coupler preparation was made in an ISO 6 clean room. The main steps of the protocol were: an ultrasonic bath during 15 min @ 50°C with Ticopur R33; coupler rinsing with ultra-pure water; drying; baking under vacuum during 60 h @ 200°C; assembly in the conditioning bench and baking in situ during 30 h @ 90 °C.

Now, we measure the number of particle at each stage of the coupler montage (See Fig. 1). The coupler is no longer baked under vacuum during 60 h @ 200°C because there was a risk of pollution for the coupler during the venting of the oven.

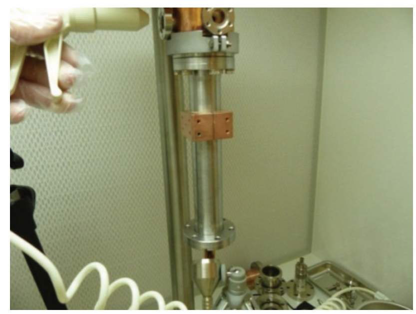

Figure 1: Counting particles.

To match the requirements, we improved the cleanliness of our assembly zone and the coupler is mounted in an ISO 4 hood placed inside our clean room. To keep the cleanliness of our conditioning bench, it is now vented with flow-controlled (< 1 l/min) filtered nitrogen. To reduce the risk of dust moving close to the coupler's window, the tip of the antenna is kept down all the time (during assembly and transportation).

In addition, electric surface field on the antenna tip inside the cavity is up to 12 MV/m, so the coupler's surface condition has been also improved. The antenna is now electro-polished (See Fig. 2) and all inner, metallic surfaces are now deoxidized (10 minutes with saturated citric acid and, for the antenna only, 2 more minutes with sulfamic acid (5 g/l)).

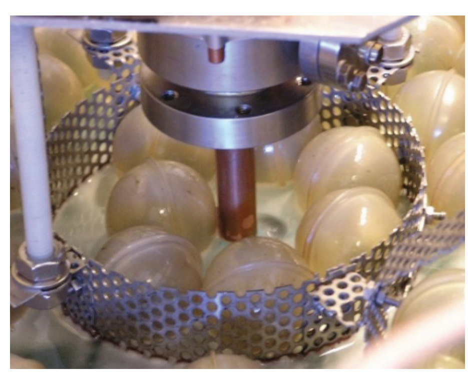

Figure 2: Antenna electro-polishing.

RF conditioning protocol

The first RF conditioning of the coupler is made at LPSC before sending the coupler to the cryomodules teams. Couplers are conditioned in a stand-alone configuration with an open termination, in a full stationary wave mode. The RF conditioning protocol was optimized in order to save time; now, the RF power is steadily increased from 0 to 20 kW CW and then lowered from 20 kW CW to 0 W. This cycle is performed twice, and then RF power is maintained at 20 kW CW for at least 1 minute. RF conditioning is performed only in continuous mode and no longer in pulsed mode. It means that RF power is always at 100% duty cycle.

Before September 2013, power was capped at 14 kW CW during one hour because the RF power couplers shall provide up to 12 kW CW beam loading power. It was decided to condition the couplers up to 20 kW CW, because it is the maximum power delivered by the SPIRAL 2 RF amplifiers. The one minute duration was chosen because it is slightly more than the time needed for the control-system to stop the RF in case of 100% reflected power.

Moreover, we do not wait anymore for the vacuum to stay under 10^{-7} mbar and for the electronic current to stay below 0.15 mA during all one conditioning cycle to stop.

RESULTS

During RF conditioning, vacuum pressure and multipactor (MP) electron current are monitored as a function of time and power. The vacuum measurement is done with a pressure gauge. For multipactor measurement, an antenna polarized to 45 V is used. This electron pickup is located close to the disc window. Interlocks on vacuum (10^{-5} mbar) and electron current (0.2 mA) are also used to secure the RF conditioning.

Results before 2012, before protocols evolution

- One low cryomodule (CM4) reached the RF specifications. The RF conditioning of the coupler, called N10, mounted inside was successful. No multipactor was observed for low power (<200W). The final vacuum was the order of 10^{-8} mbar with some peaks up to 10^{-7} mbar (See Fig. 3).

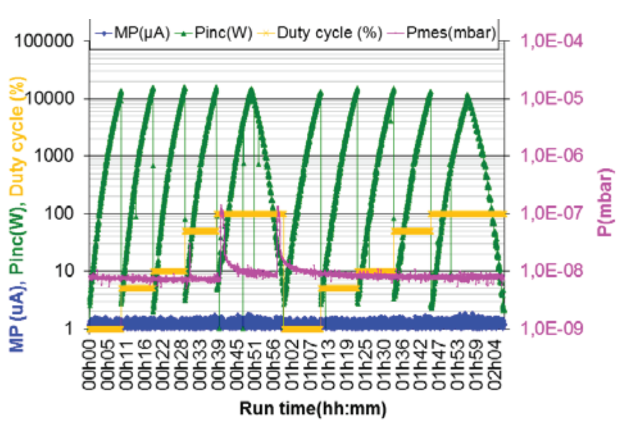

Figure 3: RF conditioning of the coupler N10.

- Three high beta cryomodules quenched below nominal gradient. After disassembly, one of the couplers' tip (coupler N4) exhibits spots (See Fig. 4).

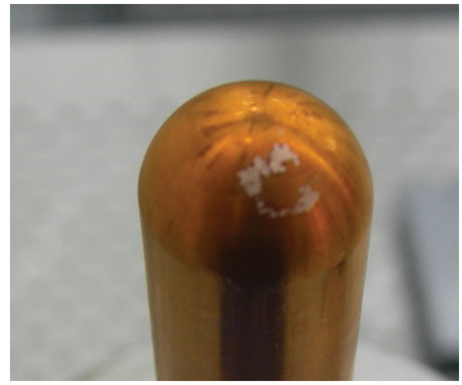

Figure 4: Spots on the tip of the antenna of the coupler N4 following a quench in the cryomodule.

Despite the quench of the cryomodule, its RF conditioning was satisfactory. Multipactor was low (peaks <0.1 mA) at low power (<200W). The final vacuum of the condition process was the order of 10^{-8} mbar. Some pressure peaks, up to 10^{-7} mbar appeared simultaneously with the multipactor peaks. (See Fig. 5).

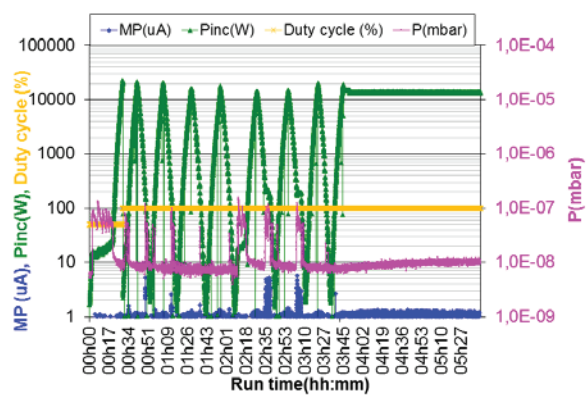

Figure 5: LPSC RF conditioning of the coupler N4.

Results after 2012, with the protocols evolution

Seventeen couplers have been processed with the new protocols. Nine of them have been mounted in the cryomodules; couplers N25, N26, N35, N8 and N7 for the beta = 0.07 cavities and couplers N13, N18, N30 and N24 for the beta = 0.12 cavities. All these cryomodules achieved the required specifications (RF, vacuum, cryogenic). There are eight other couplers ready for assembly inside the cryomodules.

Two others couplers (N28 and N4) were not conditioning at the LPSC. The results of the cryomodules tests were successful.

Examples of the RF conditioning for two couplers, N13 and N22, are given below:

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- The coupler N13 is the coupler showing the worst results since the new protocols have been applied. Even though these results, this coupler has been validated in a high beta cavity. This cavity achieved the required performances (RF, vacuum, cryogenic). The number of the particles measured when blowing with filtered nitrogen at 5 bars is much better than the specifications (see Table 1).

Table 1: Cleanliness control results of the coupler N13

Blowing	0.5 µm particles number measured	5 µm particles number measured
1srt	13	0
2nd	4	0
3rd	9	0
Specification:	*100*	*0*

During RF conditioning, this coupler N13 showed low multipactor (<0.1mA) at low power (> 200W). The final vacuum pressure is the order of $5*10^{-8}$ mbar. (See Fig. 6).

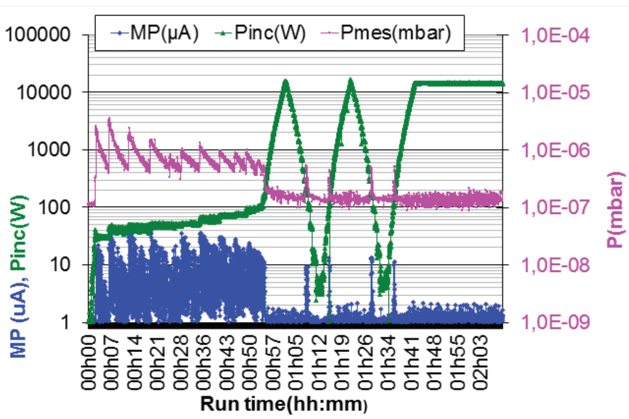

Figure 6: RF conditioning of the coupler N13.

- The last coupler conditioned in September 2013 is called N22 was excellent. The number of the particles measured when blowing with filtered nitrogen at 5 bars is much better than specifications (See Table 2).

Table 2: Cleanliness control results of the coupler N22

Blowing	0.5 µm particles number measured	5 µm particles number measured
1srt	17	0
2nd	9	0
3rd	10	0
Specification:	*100*	*0*

The results of the RF conditioning of this coupler N22 at LPSC gave no multipactor (<1µA). The final vacuum pressure is around $5*10^{-8}$ mbar (See Fig. 7). The RF conditioning was performed in one hour.

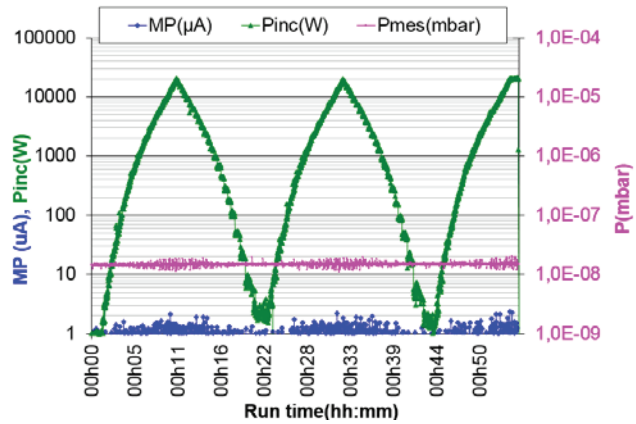

Figure 7: RF conditioning of coupler N22.

Comparison of the RF conditioning result with/without the protocols evolution

Comparing (See Fig. 8 and Fig. 9) the couplers that mentioned above, we found that in terms of multipactor the N10 and N22 were very good and similar: no multipactor was measured. For the N4, little multipactor was found. The N13 coupler exhibits more multipactor than the others. In term of vacuum measurement the N4 and N10 have a better initial and final vacuum pressure (around 10^{-8} mbar), but the N22 showed no pressure rise during conditioning. The N13 vacuum pressure curve shows a plateau ($7*10^{-6}$ mbar) with a final vacuum of 10^{-7} mbar.

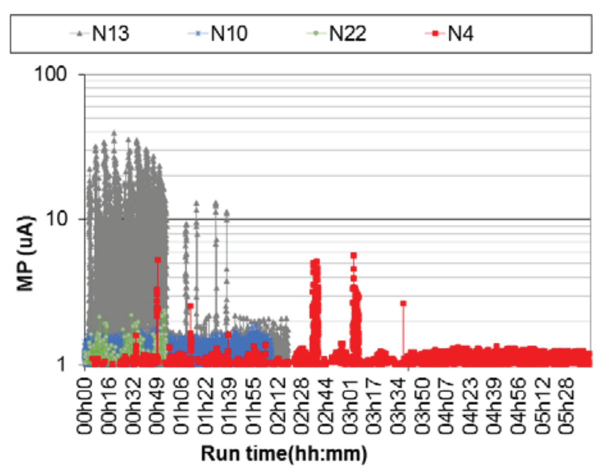

Figure 8: Multipactor versus time.

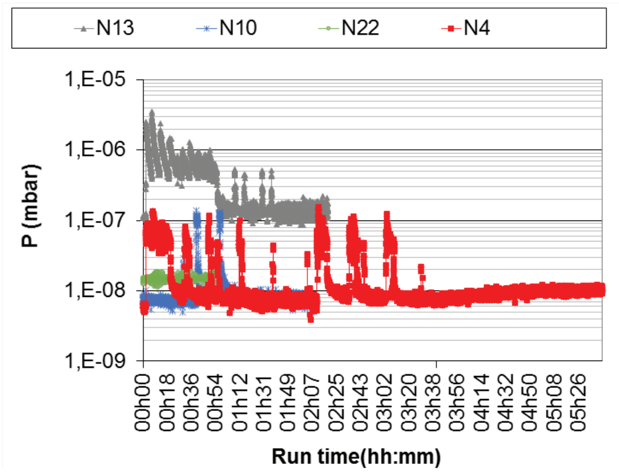

Figure 9: Vacuum measurement versus time.

In general, for the seventeen couplers (See Fig. 10 and Fig. 11) conditioned according to the last protocols, we find low current (<0.1mA) at low power (<200 W). However, these good results are sometimes worse that the ones obtained with the protocols before 2012 (for example with the coupler N4, in red).

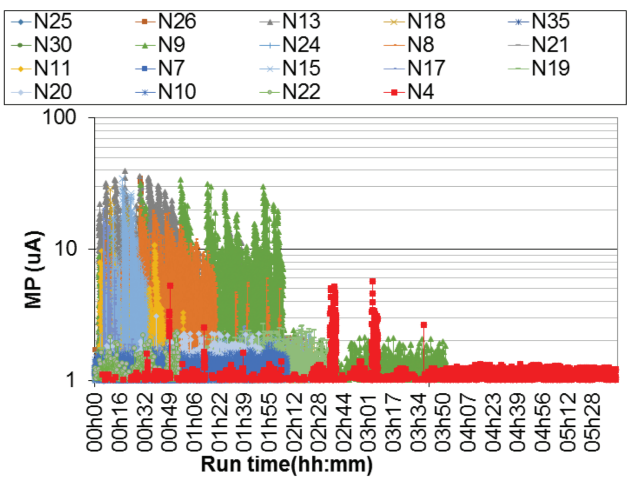

Figure 10: Multipactor versus time.

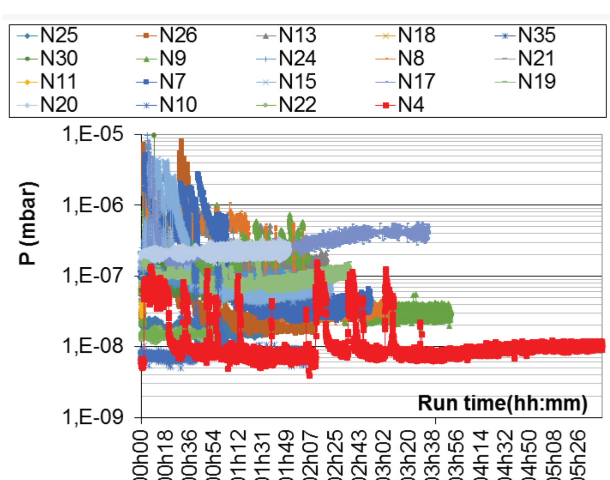

Figure 11: Pressure versus time.

CONCLUSION

To sum up, we have validated an optimised protocol for the RF conditioning of the SPIRAL 2 power couplers at LPSC (France). The last coupler (N22) was conditioned in one hour. We also see that bench conditioning seems not to be mandatory. Two cryomodules have reached easily the RF, vacuum and cryogenic specifications with unconditioned power couplers. This is probably possible thanks to the weak multipactor activity (<0.2 mA) at low power (< 200W).

In 2012, for each component mounted in the LINAC, a control of the number of particles measured was added. We improved our coupler preparation protocol to match the requirements, but this did not improve the multipactor or ultimate vacuum. Results of the RF conditioning are good and gave low MP current (< 0.1 mA) at low power (< 200 W). Meanwhile, as the couplers are no longer baked in oven and the RF conditioning is faster, we often see more multipactor and higher pressure. However, since the particles control, all the cryomodules have been tested successfully (RF, vacuum, cryogenic) and so all protocols have been validated, highlighting the importance of cleanliness.

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