IFMIF-EVEDA SRF LINAC COUPLERS TEST BENCH

D.Regidor, I.Kirpitchev, P.Méndez, J.Molla, A.Salom, M.Weber, CIEMAT, Madrid, Spain
M.Desmons, N.Grouas, P.Hardy, V.M.Hennion, H.Jenhani, F.Orsini, CEA, Gif-sur-Yvette, France

Abstract

The IFMIF-EVEDA SRF Linac is a cryomodule equipped with eight superconducting HWR cavities, operating at the frequency of 175MHz and powered by 200kW CW RF couplers. Before assembling the couplers to the cryomodule, it is necessary to process them using high levels of RF power. In order to perform this conditioning, the power couplers must be connected to a RF network which is fed by an RF source and ended with a load or a short-circuit, depending on the conditioning mode to be applied.

A test bench has been designed for the conditioning of the SRF Linac couplers. The main component is the “Test Box”, a resonant cavity where two couplers will be assembled to transmit the 200kW from the RF source to the appropriate termination. The Test Box includes a large pumping port allowing an efficient pumping of the entire vacuum volume limited by the coupler ceramic windows. Several diagnostics as light detectors, vacuum gauges and thermal transducers will provide information on the relevant parameters for the control of the RF conditioning process. In addition, a support frame has been designed to maintain the whole assembly and reduce the mechanical stress on the couplers.

INTRODUCTION

The same design of power coupler (PC) will be used in IFMIF to feed each HWR despite their diverse power needs. The PCs will be adapted to transmit the 175MHz RF power from the coaxial lines (50 Ohms) to the HWRs, withstanding RF power levels up to 200kW CW in travelling wave mode and the full reflection standing wave in pulsed mode. Additionally, they will protect the cavity vacuum from the external atmospheric pressure using a ceramic window and they will limit the thermal loads on the cavity to keep it in superconducting state [1].

The first two complete prototype PCs have been manufactured by CEA and its industrial subcontractor CPI. These prototypes have been delivered at CIEMAT to start the high power conditioning at room temperature that will allow the validation of the PCs design by CEA, leading to the start of the series manufacturing by CPI [2].

SRF Linac Couplers Handling

As the PCs must work within a superconducting machine, they are very sensitive to particle contamination. The PCs have been assembled in an ISO5 (class 100) clean room and the conditioning process must maintain this cleanness level. For this reason, special attention has been paid in the design of the vacuum system of the Test Bench to minimize particle generation during the operation and to avoid particle migration during the venting up to atmospheric pressure. Additionally, all the assembly/disassembly operations in the Test Bench will be done inside an ISO7 (class 10000) clean room. Inside this clean room there will be an area with an ISO 5 laminar flow for the critical operations like the PCs opening and their assembly in the Test Box.

TEST BENCH

In order to perform the RF conditioning, a complex RF network that includes the PCs will be used. This network will be fed by a source (the LIPAc RF Module Prototype) with the aim to pass high levels of RF power through the couplers [3]. The high field levels inside the couplers will trigger degassing and electron emitting processes that properly controlled will prepare the internal PCs surfaces to withstand the SRF Linac operating conditions [4].

To transmit the RF power from the source through the PCs, a special transition is needed to optimize the matching and the vacuum integrity. As the SRF Linac PCs will be RF processed by pairs at room temperature, an appropriate matching box (Test Box) on which two couplers can be assembled, has been manufactured.

A special assembly (the Test Bench) has been designed and manufactured to allow the integration of all the RF network and vacuum system components in a support frame that includes diagnostic, cooling, baking and control systems. To ease the assembly operations and the handling of the equipment in the different areas in which the conditioning will take place, the Test Bench has been divided in two different structures:

- Conditioning Skid: guarantees the structural integrity of the Test Box and the PCs assembled, avoiding any damage to the components during their handling and transport between clean room and RF source area.

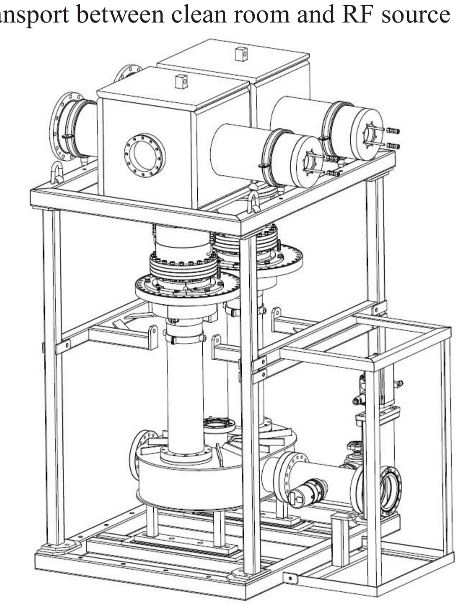

Figure 1: Conditioning Skid.

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- Main Structure: integrating all the subsystems, including the conditioning skid itself. The skid assembly is designed to allow a fast and easy connection with the main structure and subsystems.

The result is a wheeled mechanical assembly that will provide the required flexibility to connect it to the RF power source and the required termination, once inside the integration/conditioning facility.

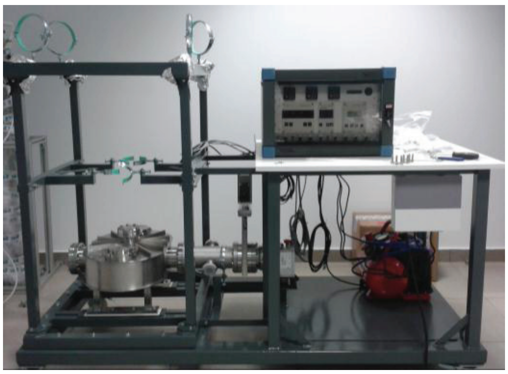

Figure 2: SRF Linac Couplers Test Bench.

Test Box

The Test Box has been designed to assemble the PCs side by side in vertical position; a horizontal arrangement would create a high mechanical stress on the ceramic windows due to the antenna weight and length.

The wave length is relatively large at 175MHz and this implies too large geometries for the simple parallelepiped shapes. Additionally, the PC antenna protrudes from the flange a very short distance, limiting the penetration of the antenna inside the Test Box and reducing the RF coupling dramatically. These constraints lead to a design using the "stadium" shape and including two "cup" structures enhancing the capacitive coupling to each PC antenna. The internal structure is made of OFHC copper to reduce the thermal losses while the external box is made of stainless steel with some stiffeners to avoid deformation in the structure due to mechanical and thermal loads. Furthermore, to reduce the temperature of the inner structure and to limit the thermal load, a cooling circuit using 5l/min of deionized water has been assembled at the Test Box base (OFHC copper part).

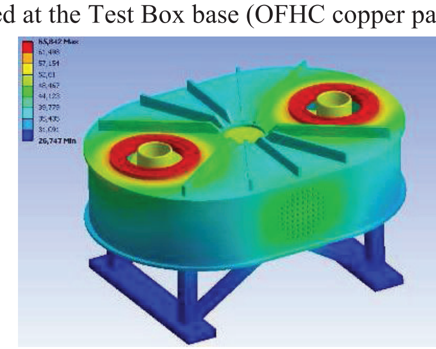

Figure 3: Test Box temperature simulation.

The vacuum inside the Test Box is made through a lateral vacuum port consisting of a cylindrical tube of 50mm length and 100mm diameter including a holed screen in the Test Box wall side and a ConFlat flange type (CF DN100) on the other side. The screen was designed to minimize the electromagnetic field penetration inside the port aperture (RF power leak into the vacuum system) while allowing a good conductance for the vacuum (calculated to be 172l/s for a total volume of 17 liters).

To compensate the RF matching variations due to mechanical manufacturing/assembly errors, a tuning system has been included in the Test Box using fixed plungers. An upper port (CF DN63) and a lateral port (CF DN100) have been added to the Test Box to insert the required plungers from the manufactured set (choosing between multiple lengths). The RF measurements done show that the Test Box has a tuning range of ±1.8MHz.

Vacuum System

To achieve the Ultra High Vacuum (UHV) required for the PCs conditioning (pressure below $5 \cdot 10^{-9}$ mbar) and to avoid the possibility of chamber contamination, a combination of oil-free roughing (roots type) and turbomolecular pumps have been assembled. Both pumps are managed by the same electronic control unit and the turbomolecular is used as part of the roughing line itself. Thus, the roughing pump also serves as backing for the turbomolecular, working both as a single pumping station.

The pressure level will be continuously measured in four different locations: each of the PC ceramic windows, the Test Box pumping port and at the turbopump inlet, just before the gate valve. For this purpose, combined Pirani/Cold Cathode gauges have been installed covering the range from atmospheric pressure down to 10^{-10} mbar. The gate valve (V1) is a low particle one (VAT series 15) controlled by the RF Module PLC taking into account the pressure difference between both sides.

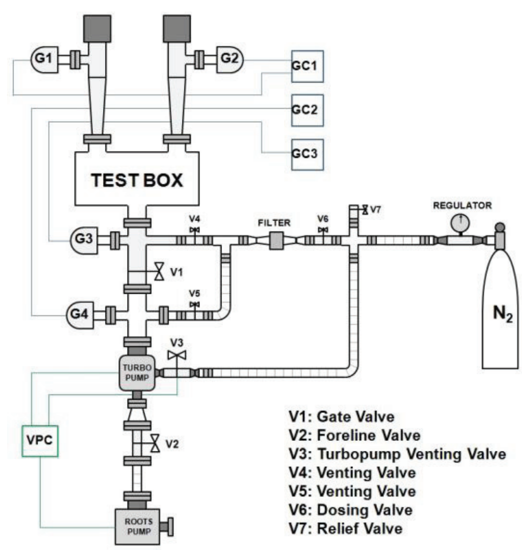

Figure 4: Test Bench vacuum system.

There have been installed three venting branches in the Test Bench. One for the turbopump with an automatically controlled valve (V3) that the pump controller (VPC) opens when the pump is stopped due to a failure and it needs to be vented. Another one to vent the vacuum chamber through a filter and at a very low rate using a dosing valve (V6). And the third one is to be able to do

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vacuum in the venting branch itself before starting the chamber venting, thus avoiding particle migration when opening the venting branch valve (V4).

Integrated Vacuum Baking

To speed up the process to reach the nominal working pressure, the Test Bench has an integrated heating system consisting of 3 independent PID controllers providing power to 3 silicone heating tapes (one for the Test Box and the other two for the PCs). This vacuum baking system has been used to test the vacuum system and the Test Box alone, reaching the target value successfully. The temperature was ramped up slowly with the vacuum system at full speed, maintained at 150ºC during 120 hours and then ramped down in the same way.

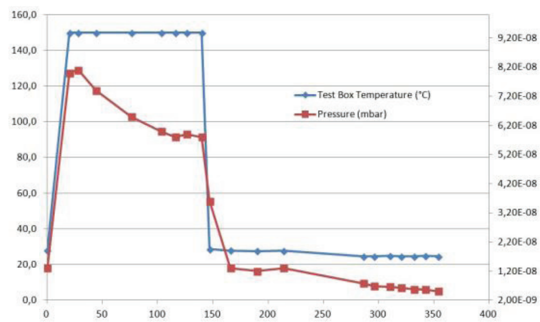

Figure 5: Test Box vacuum baking (in hours).

HIGH POWER CONDITIONING

The conditioning must be carefully controlled to provide the increasingly high power levels required to process the PCs but without surpassing the threshold that could result in a permanent damage to the internal structures. Apart from vacuum and RF power, additional parameters will be carefully monitored:

- Multipacting: the electrons trapped by an antenna (near the PC ceramic windows) at a +45V potential generate a current (few mA) that is measured with precision to evaluate the multipacting level.
- Arcs: a sapphire optic window has been installed on each PC, near the ceramic window, to detect arcing. A very high sensitivity and fast response interlock unit is connected through optic fibers to these ports.

The control system of the RF Module based on PLC will receive analog signals for data analysis purposes (vacuum and multipacting) and the Low Level RF unit (LLRF) will receive the digital interlock signals generated by each controller to provide a fast and reliable RF stop. The RF power level is managed by the control loops of the LLRF using the different measurement points [5].

Travelling Wave Mode

The nominal operating condition of the couplers is in travelling wave mode as the power will be transferred from the coaxial lines to the cavities through them. To condition the PCs in this way, all the 200kW CW power will pass through the PCs and Test Box and will be dissipated in a 250kW load used as a termination for the Test Bench RF network.

Standing Wave Mode

The worst case for the PCs operation is during the commissioning or start-up of the accelerator in which pulsed modes will be used and the cavities may reflect up to 100% of the RF power. In this case, the EM field inside the coupler could reach values up to 4 times higher than in travelling wave so it is needed to condition them for this situation. To do so, a short-circuit will be used at the output of the conditioning RF network and the reflected power will be dissipated in the 250kW load but through the reflected port of the circulator. This short-circuit is a special design using a motorized sliding short plate to allow an easy displacement of the standing wave peaks to condition the critical areas of the PCs (ceramic windows).

RF Power Control Procedure

The conditioning will start using short pulses at a predefined repetition rate. The peak power will be increased gently while no threshold is trespassed, and when full power is reached, a new round is started but using a wider pulse. In this way the RF processing is done in multiple sweeps increasing the duty cycle up to CW.

The RF will be immediately stopped (less than 10µs) if the critical vacuum, the critical multipacting or arc interlock is triggered. In case that the vacuum go over the nominal vacuum level but not exceeding the critical one, the RF power level will be maintained constant until the vacuum system is able to restore the nominal value.

NEXT STEPS

The clean room operations will be carried out at Indra Sistemas premises. After the assembly is finished, the vacuum baking will be done allowing the vacuum chamber to reach faster the target pressure level. Then, the high power conditioning of the PCs in travelling and standing wave will be performed at the integration facility where the RF Module prototype is installed [3].

ACKNOWLEDGMENT

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