VALIDATION PROCEDURES FOR THE IFMIF POWER COUPLER PROTOTYPES

H. Jenhani#, P. Carbonnier, Y. Gasser, N. Grouas, P. Hardy, V. Hennion, F. Orsini, Y. Penichot, B. Renard, D. Roudier, CEA/IRFU, Gif-sur-Yvette, France
S. Einarson, T. Treado, CPI, Beverly, Massachusetts, USA
D. Regidor, M. Weber, CIEMAT, Madrid, Spain

Abstract

In the framework of the International Fusion Materials Irradiation Facility (IFMIF), which consists of two high power CW accelerator drivers, each delivering a 125 mA deuteron beam at 40 MeV, a Linear IFMIF Prototype Accelerator (LIPAc) is presently under design for the first phase of the project. The first two IFMIF Power Coupler (PC) Prototypes were manufactured for LIPAc. Series of acceptance tests have been performed successfully. Prototype PCs have been then cleaned and assembled in an ISO 5 cleanroom. A dedicated test bench allowing RF conditioning of the couplers up to 200 kW CW at 175 MHz was achieved. RF power conditioning is planned to start during October 2013.

INTRODUCTION

Design and validation of the first IFMIF cryomodule will be achieved in the frame of the Engineering Validation and Engineering Design Activities program (IFMIF-EVEDA) [1]. This cryomodule will include eight Power Couplers (PC), eight superconductive HWRs and eight Solenoid Packages. It was decided that only one coupler design will be used for all the HWRs despite their diverse power needs. PCs should be able to withstand RF power tests up to 200 kW at 175 MHz in CW travelling wave mode and in pulsed full reflection mode.

The coupler design was shared between CEA and the PC manufacturer CPI [2], in respect to the CEA detailed Specification and Requirements Document [3].

Several manufacturing processes and design aspects have been validated before manufacturing the prototypes. A full window set with a truncated antenna and a RF matching transition called "T" transition (see figure 1) were manufactured. This stage was very important to validate the RF design and discuss the manufacturing quality needed before the production of PC prototypes [2].

Two PC prototype sets have been delivered to CEA. The validation of these couplers will allow the start of the productions of eight PC series.

This paper will summarise the main acceptances tests already performed on the PC prototypes, the cleaning procedure for their vacuum parts and the RF conditioning procedure to be performed for the RF power validation of the PCs.

POWER COUPLER LAYOUT

The IFMIF coupler has a 50 Ω coaxial geometry and consists of three main parts: RF window, "T" transition and cooled outer conductor (see figure 1). In order to reduce the RF power losses heating effects, many design options were decided. Three water cooling circuits (see figure 2) are used to cool independently the antenna, the inner conductor of the "T" transition and the window ceramic. This ceramic is made of high purity alumina (AL995) to have low tangent delta losses. The anti-multipacting TiN layer thickness on ceramic is also optimized to reduce these losses. Except the "T" transition outer conductor, made of aluminium, all the RF surfaces are bulk or coated OFHC copper. An active GHe cooling system is used to interface the SC cavity with the room temperature. This allows more control flexibility on the temperature profile along the cooled outer conductor.

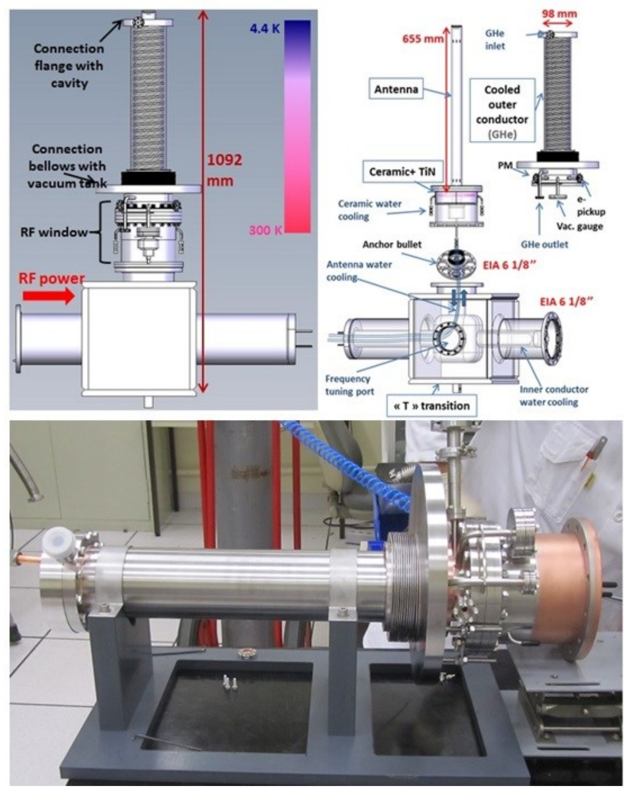

Figure 1: IFMIF Power Coupler layout.

More detailed description of the PC is given in [2].

ACCEPTANCE TESTS AND CONTROLS

As it was already mentioned, the main manufacturing processes have been already validated on a complete window with a truncated antenna and a "T" transition [2]:

#Correspondent author: hassen.jenhani@cea.fr

ISBN 978-3-95450-143-4

The cooper plating quality, the TiN thickness, the Low Level RF behaviour and the quality of the manufacturing. In addition, several acceptance tests and controls have been performed on the PC prototypes before their delivery.

Leak Tests

Prior to the final leak tests the cooled outer conductor was subjected to 5 successive thermal cycles from room temperature to liquid nitrogen temperature in a bath of liquid nitrogen. Vacuum leak tests were carried out. The window and the cooled outer conductor were leak checked coupled together using the same choice of Helicoflex and Conflat gasket seals as the ones to be used for the final PC assembly on the accelerator. The Helicoflex seal gasket was sealed against a stainless steel flange with the same groove detail that was used on the cavity flange. Calibrations took place prior to the tests. The test starts with an initial leak check by spraying components with helium. Then, a second check was performed with the unit bagged, to completely immerse the outside of the coupler with helium. The leak rate requirement, corresponding to a value lower than 10^{-11} Pa.m^3/S, was obtained.

Desorption Rate Test

Desorption rate test was performed on the final PC vacuum parts assembled together. The test set-up utilized two pressure gauges with a small known conductance in between. The quantity of gas flowing from the coupler through the conductance orifice can be determined based on the two pressure measurements difference. The estimated desorption rate was three times less than the required specification of 5×10^{-9} Pa.m/S.

GHe Cooling Circuit Test

The helium cooling circuit is a pressurized circuit with a nominal input GHe pressure of 0.12 MPa. This circuit must sustain four times its nominal pressure in order to comply with Japanese regulation for the PCs operation at Rokkasho. Each cooled outer conductor has been pressurized to 0.6 MPa. No distortion has been observed. Leak tightness was preserved. The pressure drop has been measured with ambient temperature nitrogen flowing from 0.12 MPa to atmospheric pressure, and found compliant with calculation.

Water Cooling Circuits

A hydrostatic pressure test was run using water coolant on each flow channel to qualify the pressure capability, and to check for leaks. The pressure drop corresponding to each circuit has been measured for its relative nominal flow. Then, the coolant flow channel was operated at twice the maximum pressure that was experienced during the flow tests.

Acceptance is based on having no leaks, while holding hydrostatic pressure throughout the test. This was obtained for all the parts.

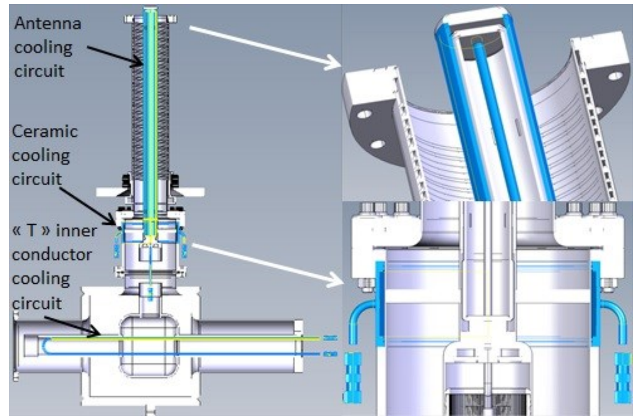

Figure 2: PC water cooling circuits

Visual Inspection

Meticulous inspection has been elaborated on all the coupler parts, following an inspection procedure based on more than sixty points of observation. All the observations are systematically written in an inspection file allowing the comparison of all the couplers manufacturing quality in addition to the recording of the progress obtained on each reworked coupler part.

Assembly and Disassembly Tests

All the parts of the coupler sets are totally assembled together, and then disassembled, several times, in order to make sure that these operations have no consequence on the coupler integrity. This allows learning about the precautions which have to be taken for the next assembly and disassembly operations to be performed.

CLEANING PROCEDURE

To have coherent cleaning procedures with HWR cavities cleanliness, vacuum parts of the PC (window and cooled outer conductor) are assembled in an ISO5 cleanroom class (see figure 3). An appropriate cleaning procedure was elaborated for each coupler part, each diagnostic element and each accessory to be assembled in the ISO5 area. Detailed arguments and tests to validate these choices are not detailed in this document. However, a summary of the coupler parts cleaning procedure steps is listed below:

- Ultrasonic bath cleaning using ultrapure water and using Tickopur R33 (2.5%) at 50°C during 15 minutes.
- Several ultrapure water rinses: No foams should be observed after rinsing.
- Rapid ultrapure air drying to avoid copper oxidation.
- Rapid enclose of the parts with dedicated clean tools to avoid contamination.
- Transportation to the cleanroom with plastic bag packaging.
- Remove of the plastic bag in an ISO7 clean area and placing of the PC parts rapidly in an ISO6 clean area.
- The parts are then passed to ISO5 laminar flow.
- Drying under an ISO5 laminar flow during 48 h.

Figure 3: Cleaning and assembly of the PC prototypes.

- Particle counting: The measured particle rate should be compliant with ISO5 cleanliness.
- Assembly of the PC vacuum parts in the same area.
- Enclosing of the coupler with special container having an adapted interface with the pumping system.
- Leak testing in the same clean room.
- Filling of the PC with dry nitrogen and closing it hermitically.
- Packaging of the coupler assembly with adapted plastic bag.
- Storage of the PCs.

The PCs are then packaged and transported from the CEA premises at Saclay to Madrid in order to be RF conditioned by CIEMAT.

RF POWER CONDITIONING PREPARATION

An RF power test facility has been achieved by CIEMAT in order perform the LIPAc PCs RF processing [4]. A specially designed Test Bench, with an actively water cooled Test Box allowing the test of the PCs by pairs, is used. The vacuum system assembly is hydrocarbon free, low particle rate generation compliant and has an adapted venting system. The assembly of the couplers on the Test Box will be performed in an ISO5 cleanroom area.

Concerning RF power validation, despite the design target value of 200 kW CW for the IFMIF PCs, all the PCs to be manufactured for LIPAc will have to deliver much lower maximum RF power, during operation. Consequently, the PCs can be totally validated for LIPAc, if they are validated for its operation power range. For that reason, it makes sense to proceed to validate the prototype PCs for LIPAc, at first. This will allow giving the green light for the PC series production. Afterward, RF conditioning will be continued in order to reach the design target RF power value. Accordingly, the RF power validation process is organized in the following way:

- First phase: The validation for the EVEDA operation which maximum RF power is 70 kW CW. The considered validation RF power for this phase is limited to 100 kW.
- Second phase: The validation for the IFMIF operation which maximum RF power is 145 kW CW.

ISBN 978-3-95450-143-4

The considered validation RF power for this phase is 200 kW (equal to the design target RF power value).

For both of the two validation phases, the conditioning sequence will be the same as giving in figure 4.

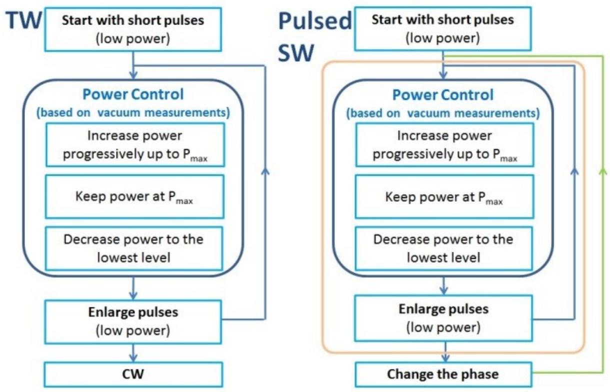

Figure 4: The RF conditioning sequence. P_{max} is the maximum RF power to reach.

SUMMARY

The IFMIF PC Prototypes have been manufactured and delivered to CEA. Many acceptance tests and controls have been performed at the manufacturer premises before the PCs delivery. All the parts have been cleaned and checked using a particle counter. The PCs were, then packaged and sent to Madrid in order to be RF processed by CIEMAT. The RF power validation of the PC Prototypes will allow the start of the PCs series production.

ACKNOWLEDGMENT

The authors would like to thank S. Berry for his fruitful advices and C. Madec for the support giving to the cleaning activities.

We would like to thank J. Novo, C. Servouin and F. Eozenou for their contribution to the PCs cleaning.

REFERENCES

[1] A. Mosnier et al., “The Accelerator Prototype of the IFMIF/EVEDA Project”, MOPEC056, IPAC 2010, Kyoto, Japan.

[2] H. Jenhani et al., “Input Power Coupler for the IFMIF SRF LINAC”, WEPPC001, IPAC 2012, New Orleans, USA.

[3] “Specification and requirements of the RF couplers”, IFMIF-EVEDA-ASG-DL09-S010-A, 25/09/2009.

[4] D. Regidor et al., “IFMIF-EVEDA SRF Linac Couplers Test Bench”, WEPWO043, IPAC 2013, Shanghai, China.