ASSEMBLY PREPARATION OF THE IFMIF SRF CRYOMODULE

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Abstract

This article presents the preparation work performed by CEA for the assembly of the IFMIF Cryomodule. Before the shipping of the components to Japan many tests and trial assemblies has been realized on the CEA site of Saclay, France. The cryomodule, which is part of the Linear IFMIF Prototype Accelerator (LIPAc) under construction at Rokkasho Fusion Institute in Japan, will be assembled there under the responsibility of F4E (Fusion for Energy) with CEA assistance. To fulfil the assembly of the cavity string, a cleanroom will be built at Rokkasho under the responsibility of QST (Quantum & Radiological Science and Technology) [1].

THE IFMIF CAVITY STRING

The cavity string of the IFMIF SRF cryomodule (Fig. 1) is an assembly of height cavities (half wave, 175 MHz) with their power couplers, height superconducting focusing solenoids with their BPMs (Beam Position Monitor), two cold-warm transitions with their beam gate valves and one pumping line. The whole string is supported by a titanium frame. Part of the LIPAc, the SRF cryomodule will be assembled in Rokkasho, Japan. Most of the cryomodule components are manufactured and ready to be ship to Japan. The current status of the cryomodule is presented in [2].

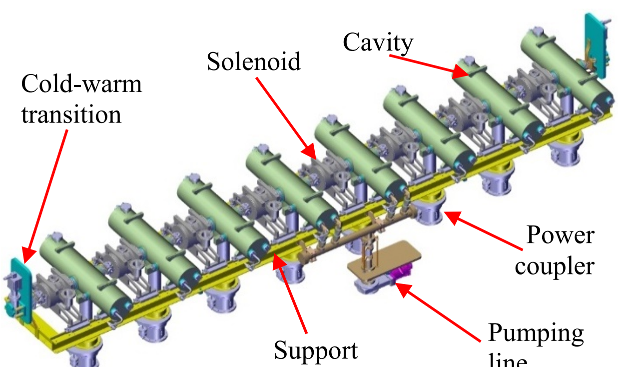

Figure 1: IFMIF cavity string assembly

To ensure a good performance of the accelerating cavities, the assembly of the string have to be done in a dust free environment. In fact, cavities are very sensitive to external contaminant that may produce field emission or thermal breakdown of the superconducting state. The assembly will be performed in an ISO class 5 cleanroom environment. A great care is given to material aspects and welding to ease the cleaning and avoid any dust contamination of the beam line during the assembly. For instance, the titanium support frame (5.5 m long) is treated to get a good surface finish.

CLEANROOM COMPONENTS: TESTS & TRIALS

BPM Buttons

The solenoids are under the responsibility of CIEMAT. As described in [3], cold beam position monitor (BPM) is part of the solenoid package. CEA tested and validated a cleaning procedure for the buttons of the BPM. As part of the cleanroom assembly, the cleanliness of the 32 buttons shall be guaranteed to avoid any contamination of the superconducting cavities. To do so, every button is cleaned in an ultrasonic bath with detergent and then rinsed with ultra-pure water. Once dry, each button shall be carefully blown with ionized filtered nitrogen. A particle counter is used to monitor the absence of particle emission (Fig. 2).

The Test Bench

A test bench has been developed and used at CEA to test, improve and validate key phases of the cavity string assembly. The test bench represent a bit more than one height of the real frame and allows the positioning and assembly a cavity/coupler assembly and a solenoid [4].

Positioning and assembly of the elements are made with a linear guide system fixed onto the frame. Sliding carriages support the cavities and the solenoids. A C-template system with gauges allows their positioning with respect to the beam axis by using the adjustment screws installed on the carriages

Mock-ups of a cavity, a coupler and a solenoid were manufactured and used in trials assemblies outside the cleanroom. These assemblies led to minor improvements such as new adjustment screws, carriages without slack, new C-templates and gauges.

Figure 2: nitrogen blowing of a BPM button before its assembly

An assembly in cleanroom conditions has then been realized with the dummy components and the BPM buttons (Figure 3). The mounting of the buttons onto the solenoid was tested with a monitoring of particle emission and shown very good result despite the dummy solenoid was not high pressure rinsed as it is foreseen for the real ones [5]. Then the positioning and assembly sequence of a cavity and a solenoid were realized. This assembly trial allowed to define the minimum distance between the elements of the string for a correct removal of the beam flanges and easy assembly by the cleanroom operators [6]. This data is very important for the assembly sequence of the cavity string. Indeed, because of the strengthening bars of the frame which is used as a support for the assembly in clean room, the displacement of the vertical coupler is limited and by consequence the number of components which could be positioned on the frame before being connected together.

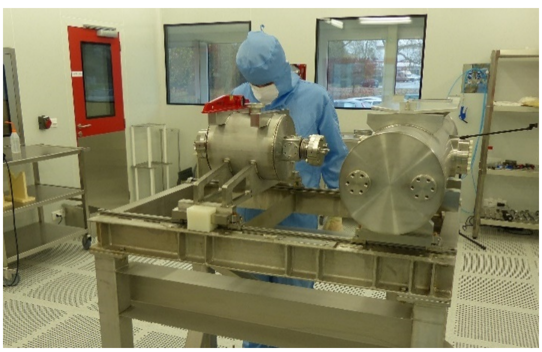

Figure 3: trial assembly in cleanroom with dummy components

Based on the experience acquired with the test bench, a sequence for the assembly of the cavity string has been written by CEA. It first describes the linear guide system used to move the elements along the frame and describes how to position the cavities and the solenoids. In fact, to limit the stress on the bellows and to be as close as possible to the beam axis, calibrated gages and C-templates (similar to the final C-shaped element) are used to precisely position each element of the cavity string (see Fig. 4). When in good position the gauges fit perfectly in the free space between the C-template and the supports.

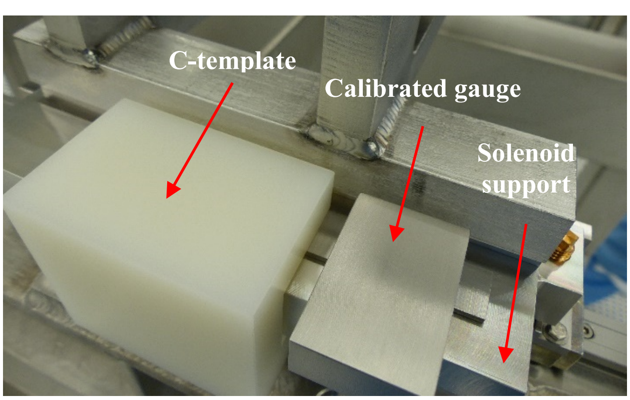

Figure 4: solenoid positioning with a C-template and a gauge

Cavity Coupler Assembly

One of the first operations to be performed in clean room for the assembly of the cavity string is to install the power couplers on the cavities. In the frame of the SaTHoRI (Satellite de Test Horizontal des Résonateurs IFMIF) test, which aims at characterizing a cavity equipped with its power coupler and tuning system is a cryomodule like condition, a tooling allowing the assembly of a coupler and a cavity was manufactured. The aim of the SaTHoRI cryostat is to test a cavity with its power coupler and tuning system in the final cryomodule configuration i.e. horizontal test.

The tooling and assembly sequence were first tested with the dummy cavity and power coupler outside of the cleanroom. Real components were then assembled in cleanroom conditions to perform the SaTHoRI test. As shown on Fig. 5 the cavity is horizontal and the power coupler is raised under the cavity for the assembly. The tooling allows the the adjustment of both cavity and coupler and their mutual alignment. An over pressure of filtered nitrogen was applied in the cavity when its coupler port was opened in order to avoid dust contamination.

The SaTHoRI test of the pre-serial cavity was successful, validating the tooling and the assembly operations [7]. However, minor improvements shall be implemented for the tooling which will be used for the assembly of the cavity string.

Figure 5: cavity coupler assembly in cleanroom, cavity installation onto the bench

NEEDLE BEARINGS AND C-SHAPED ELEMENTS

In order to manage the thermal contraction of the frame and to guarantee the correct positioning of the string elements, each of them lays on needle bearings and C-shape assembly, similar to the system used described in [8].

However original bearings were subject to magnetization [9]. Because of their location, next to a region where the magnetic field is maximum, it was decided to manufacture new bearings free of magnetic materials [10]. The cages that contain the ceramic needles are made of brass

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and a brass staple used to enclose the needles is glue with Stycast® (see Fig. 6).

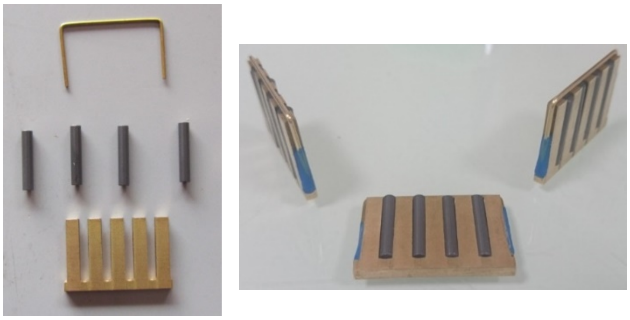

Figure 6: IFMIF needles bearing

A set of C-shaped and bearing elements were manufactured as part of the test bench. A gluing test of the staple was done, followed by three thermal shocks in liquid nitrogen. No defect was observed after the thermal shock and an assembly was performed on the test bench using the dummy components.

CRYOMODULE COMPONENTS: ASSEMBLY TESTS

As described in [1], the cryomodule is made of many components. As it will be assembled in Japan, it is mandatory to control every parts. Therefore, each part is controlled: visual inspection, dimensional control, leak test and pressure tests when necessary. Moreover, several blank assembly have been performed to control the interfaces between sub-systems:

- A blank assembly of the thermal shield in the vacuum vessel was performed at the manufacturer's premises before the welding of the pipes on the panels (Fig. 7).
- After the manufacturing of the panels of the magnetic shield and before heat treatment, a blank assembly of the shield in the vacuum vessel has been performed at CEA. Due to minor manufacturing defects of the vacuum vessel, some holes in the panels had to be enlarged and special washers manufactured.

Figure 7: blank assembly of the thermal shield inside the vacuum vessel.

SUMMARY

To prepare the assembly of the LIPAc cryomodule at the Rokkasho Fusion Institute, many efforts have been made by CEA using dummy components and the test bench to test, validate and improve the assembly sequence of the cavity string in cleanroom. In addition a large number of components have been tested and/or verified after their manufacturing prior to shipment to Japan. And many technical documents have been written, as CEA will only provide assistance for the assembly of the cryomodule.

ACKNOWLEDGMENTS

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