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TOOLING SYSTEMS FOR THE ASSEMBLY AND INTEGRATION OF THE SSR1 CRYOMODULE FOR PIP-II PROJECT AT FERMILAB*

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Abstract

In this paper we present the assembly strategy and tooling design for the SSR1 cryomodule from the cavity string to the final module. Several challenging aspects were considered to minimize undesired stresses on critical components, to preserve the alignment of cavities and solenoids during final assembly, and ultimately to meet the technical requirements of the PIP-II project at Fermilab.

INTRODUCTION

The PIP-II project at Fermilab is a proton driver superconducting linac that consists of five different SRF cavity types: half wave resonator (HWR), 325MHz single spoke resonators (SSR1, SSR2), 650 MHz multicell cavities (LB650, HB650). The design of the first SSR1 cryomodule is in the advanced stages [1]. The assembly strategy plan is presented along with the tooling systems developed for this scope of work.

The cavity string assembly of the SSR1 cryomodule consists of eight single spoke resonators type 1 (SSR1) with vacuum-end couplers, four solenoids and beam position monitor (BPMs) sub-assemblies, with ultra high-vacuum gate valve sub-assemblies terminating the beamline at each end.

The coldmass integrates the cavity and solenoid string on a full-length strongback. The design of thermal shielding and support posts is such that the strongback remains at room temperature while the active components are at 2 K. This solution preserves the precise alignment of cavities and solenoids performed prior to the insertion of the coldmass unit into the vacuum vessel for the final assembly.

Fixtures and tooling have been designed to handle and assemble components and sub-assemblies from the string assembly to the final cryomodule assembly. These fixtures and tooling are required to be compatible for the assembly of SSR1, SSR2, LB650, HB650 cryomodules to the greatest extent possible.

Work Stations at Lab 2

The first SSR1 cryomodule for PIP-II will be assembled in the Fermilab Lab 2 facility starting from cavity string assembly in a class 10 (ISO 4) cleanroom to the final cryomodule assembly. The cavities are being prepared and qualified elsewhere [2], [3]. The assembly strategy is defined which includes all activities taking place in the four work stations (WS), as shown in Fig. 1. WS 1 is the cleanrooms complex where components of the string assembly are received, cleaned, prepared, and assembled. Upon completion, the string is rolled out of the cleanroom to the lifting area (WS 2) where it is removed from the cleanroom posts and mounted on the strongback sub-assembly (pre-assembled in WS 3). The coldmass assembly is made in the WS 3 which is fully covered by the crane system to facilitate the handling and assembling of heavy components (i.e. two-phase pipe, thermal shields, etc.). The insertion of the coldmass into the vacuum vessel and the final cryomodule assembly activities takes place in WS 4.

TOOLING FOR STRING ASSEMBLY

The components of the string assembly are assembled in a class 10 (ISO 4) cleanroom using a series of tools specifically designed to improve handling, maintain a high level of cleanness, enable a precise alignment and reduce the possibility of human errors. During the design phase, cleanroom best practices were applied including: positioning moving parts below the string beam-line to lower the risk of particulate contamination; using cleanroom compatible materials like electro-polished 304 stainless steel (SS), anodized 6061 Aluminum, bronze, Titanium. A set of cleanroom tooling was procured and tested to assemble the SSR1 cavities string:

- Movable rail system
- Solenoid-BPM-Bellows subassembly tool
- Solenoid-BPM-Bellows alignment tool
- Bellows cages
- Beam pipe end subassembly tool
- Nitrogen purging line

These components are all designed to structurally support the weight of cavities and solenoids, and the vacuum forces [4] with resulting small elastic deformations. This is a necessary condition to minimize undesired stress on critical components such as bellows and UHV flanged connections and to maintain the positioning/alignment of components to the sub-millimeter scale.

Movable Rail System

A rail system with sliding cleanroom posts, shown in Fig. 2, is needed to allow the challenging connection of cavities back-to-back with a very narrow gap (about 20 mm) when in the nominal position. Sliding cleanroom posts facilitate the overall assembly process. Moreover, the rail system was designed to be movable in order to position the cavities string where the best air flow conditions (i.e. speed, laminarity) are identified in the cleanroom. W wheeled rail system allows the positioning of the string assembly in proximity of the cleanroom exit. The risk of the uneven floor was mitigated by using shock absorbing wheels, see Fig. 2.

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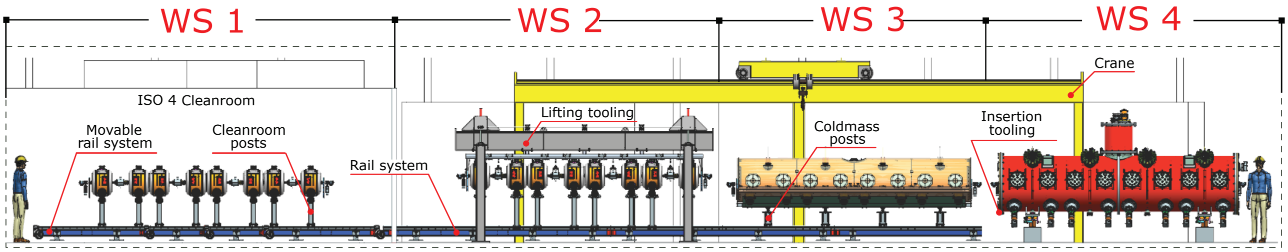

Figure 1: Layout of work stations at Lab 2 for the assembly of SSR1 cryomodule.

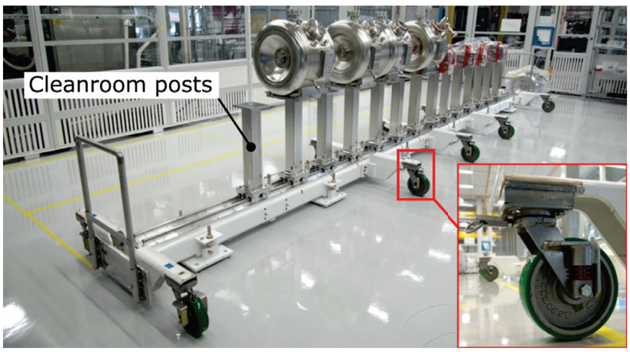

Figure 2: Movable rail system in the class 10 cleanroom.

Tooling for Solenoid-BPM Subassembly

A movable lifting cart equipped with a custom rotatable platform (Fig. 3-left) was designed to assemble, handle and position the solenoid-BPM subassembly, minimizing the risk of particulate contamination. Once the sub-assembly is completed and leak checked, it is laid down on support tooling sitting on the movable rail system support post (Fig. 3-right). Positioning tooling with five degrees of freedom is placed between the cleanroom post and the solenoid-BPM subassembly to allow the alignment to the sub-millimeter scale. Each bellows is equipped with an adjustable cage that allows the bellows flanges to be parallel to the cavity flanges. The cage also serves to sustain the vacuum forces during leak check. The cage is be removed after the completion of the string assembly.

Figure 3: Tools for solenoid subassembly.

Tooling for Beam-pipe-end Subassembly

The beam-pipe-end subassemblies are assembled on an adjustable stand placed on a cleanroom post, as shown in Fig. 4. The regulation of the adjustable stand and the axial movement of the cleanroom post facilitate the connection of the beam-pipe-end subassembly to cavity.

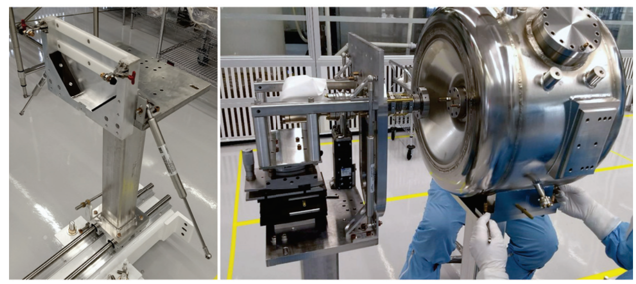

Figure 4: Beam pipe end-subassembly tooling.

Tooling for Cavity-to-cavity Connection

The cavity to cavity connection requires that an edge-welded bellows get stretched using an adjustable cage to provide room for the flange connections. Then the installation is done manually on one side. The other connection is done by adjusting the position of the bellows flange with the adjustable cage and by moving the cavity axially on the rail, see Fig. 5.

Figure 5: Cavity to cavity beam-line connection.

Nitrogen Purging Line

Cavities are purged with nitrogen before the removal of the beam pipe blanks to avoid particulates falling inside the beam volume. The purging line is equipped with an in-line high-purity filter and a mass flow controller to adjust the Nitrogen flow. Fig. 6 shows the importance of setting an

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active Nitrogen purging with a mass flow controller (set to 4 SLPM) to prevent back flow in the cavity beam port opening.

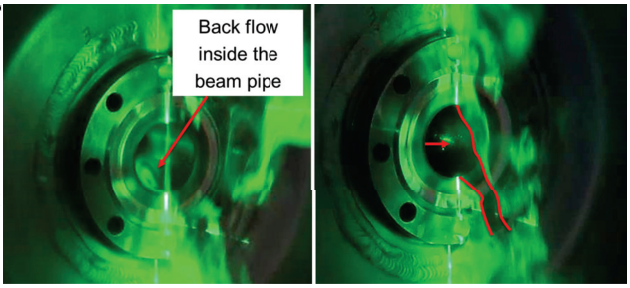

Figure 6: Air flow near by the cavity beam pipe port without (left) and with (right) an active nitrogen purging.

TOOLING FOR COLDMASS ASSEMBLY

Coldmass assembly tooling is designed to support the integration of the cavity string into the coldmass assembly. A rail system was designed to allow to movement of the string assembly and the coldmass assembly from WS 2 to WS 4 maintaining the alignment with the tooling installed at each WS. The lifting tooling at WS 2 is needed to transfer the string assembly from the cleanroom posts to the cavity and solenoid support posts mounted on the coldmass strongback sub-assembly. The transition from WS 2 to WS 3 is done by sliding the coldmass posts on the rail system.

Lifting Tooling

The lifting tooling shown in Fig. 7 is designed to safely lift the entire string assembly meeting the requirements of ASME BTH-1 code [5]. The stiffness of the entire system was checked and verified under several loading conditions in order to avoid undesirable loads on critical components like the bellows and UHV connections. The jacking system regulating the vertical displacement of the top frame is made of worm screws synchronized by a transmission mechanism. This lifting tooling is designed to be used also for the string assembly of SSR2, LB650, and HB650 cryomodules.

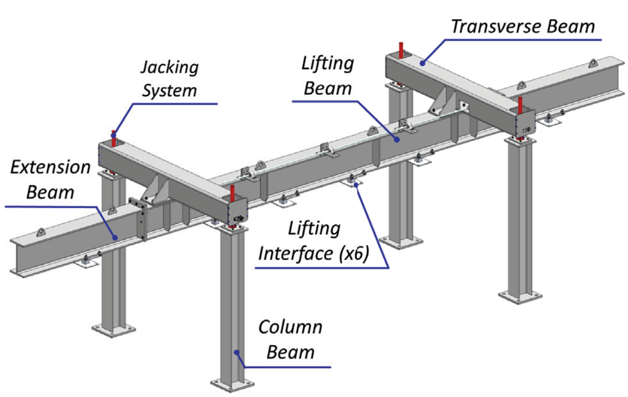

Figure 7: Lifting tooling.

Rail System and Coldmass Posts

The coldmass rail consists of a structural tube supporting aluminum guides on which the coldmass posts can slide as shown in Fig. 1. The rail guides match the type used for the cleanroom to maintain compatibility for the cleanroom posts. The rail can be leveled by adjustable supports anchored to the floor. Finite element analysis and calculations were performed in order to assure that the structural deformations are in an acceptable range and that the bearings can hold the distributed weight of the coldmass.

TOOLING FOR FINAL ASSEMBLY

Coldmass Insertion Tooling

The insertion tooling is designed to insert the coldmass assembly into the vacuum vessel. It consists of a custom conveyor roller shown in Fig. 8 installed inside the vacuum vessel prior the insertion. A hydraulic lifting system has been integrated into the insertion tooling to move down the coldmass on the vacuum vessel supports and to pull out the tooling from the vacuum vessel.

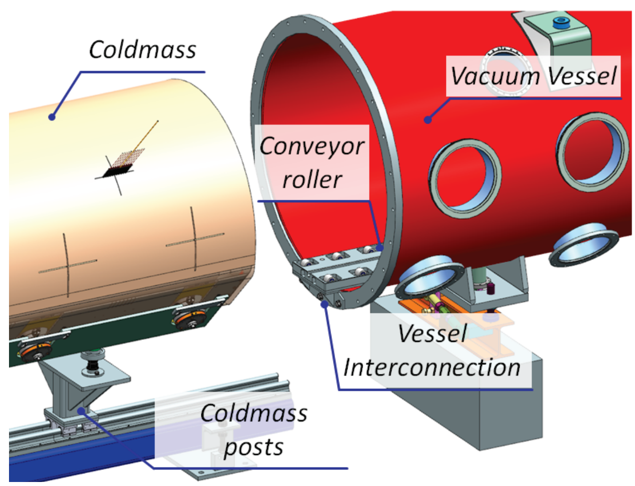

Figure 8: Insertion of the coldmass into the vacuum vessel.

CONCLUSION

The assembly strategy for the SSR1 cryomodule has been defined and it will be finalized with additional details in the coming months. The basic set of tooling were designed and reviewed. The validation of this assembly strategy for the SSR1 cryomodule will serve as baseline for the integration of SSR2, LB650 and HB650 cryomodules for PIP-II.

REFERENCES

[1] V. Roger *et al.*, "Design update of the SSR1 cryomodule for PIP-II project", presented at IPAC18, Vancouver, Canada, Apr.-May 2018, paper WEPML019, this conference.

[2] D. Passarelli *et al.*, "Preparation and Qualification of Jacketed SSR1 Cavities for String Assembly at Fermilab", presented at IPAC18, Vancouver, Canada, Apr.-May 2018, paper WEPML015, this conference.

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[3] M. Parise, "Preparation, processing, assembling and testing of spoke resonators: from SSR1 jacketed cavities to string assembly", TESLA Technology Collaboration (TTC) Meeting, Milan, Italy, 2018. https://agenda.infn.it/contributionDisplay.py?contribId=53&sessionId=9&confId=13791

[4] D. Passarelli *et al.*, "High-Vacuum simulations and measurements on the SSR1 cryomodule beam-line", in *Proc. SRF'15*, Canada, 2015, paper TUPB074.

[5] Design of Below-the-Hook Lifting Devices ASME BTH-1-2017.