SUPERCONDUCTING NIOBIUM RESONATOR FABRICATION AND TESTING AT IUAC

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Abstract

Inter-University Accelerator Centre is currently constructing fifteen niobium quarter wave resonators for the superconducting linear accelerator project. The production is presently nearing its completion. In addition to building resonators for the in-house programmes, a project to build 325 MHz single spoke resonators for the proton driver linac for Fermi National Laboratory will begin soon. This paper presents details of the current resonator production work and future plans at IUAC.

INTRODUCTION

The Superconducting Resonator Fabrication Facility (SuRFF) consisting of an electron beam welding machine, surface preparation lab and high vacuum furnace, for constructing niobium quarter wave resonators (fig. 1) for the linear accelerator [1], has been operational at Inter-University Accelerator Centre (IUAC) since July '2002 [2]. In the first phase a single quarter wave resonator (QWR) was successfully fabricated and tested [3]. It has been installed in the rebuncher cryostat of the linac and operated at 3.3 MV/m with 6 W RF input power [4]. In the second phase two more completely indigenous QWRs were fabricated. Figure 2 shows one of the resonators along with its niobium slow tuner bellows [5]. In cold test at 4.5 K the low field Q_0 on this resonator was measured to be $\sim 1.5 \times 10^9$, and with very little high power pulse conditioning it performed at 3.5 MV/m accelerating electric field with 3.5 W RF input power, exceeding the nominal design goal. Following the successful testing of the fully indigenously built resonators, production of fifteen more QWRs for the second and third linac modules began in July '2005 [6].

PRODUCTION OF QWRs

The resonator production is being done using both, the facilities setup at IUAC as well as commercial vendors. All the machining, forming, rolling and fitting of the niobium components and assemblies along with the fabrication of the outer stainless steel vessel are being done at a local vendor's site. Substantial amount of developmental work had been undertaken during the construction of the first two indigenous resonators to train the manpower in various machining and sheet metal works and in handling of the niobium material. This was done keeping the future resonator production and other projects in mind. All electron beam welding, electropolishing, heat treatment and testing are done using the SuRFF facilities setup at IUAC.

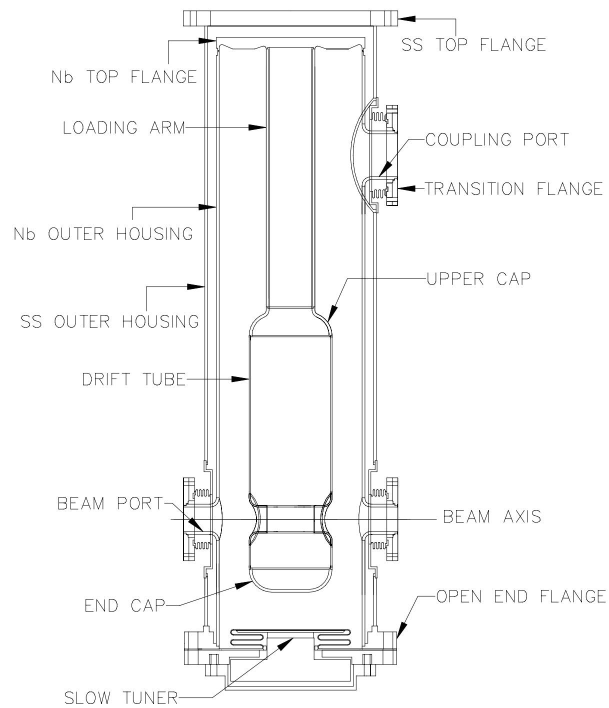

Figure 1: Schematic diagram of IUAC-QWR

Figure 2: One, of the two, fully indigenously built QWRs at IUAC along with its niobium slow tuner bellows.

The resonator production is being done with sufficient contingency of extra parts. Simultaneously the drift tubes of three existing resonators are also being repaired. Therefore the present effort can be considered equivalent to constructing eighteen complete resonators. For the production work the electron beam welding fixtures have been designed, wherever possible, to weld several pieces in a single pump down to increase productivity and save effort & time. Similarly the electropolishing work is planned so that several niobium assemblies can be polished in a single setup. Most of the tooling and fixtures for the production work is available from previous constructions. However, some additional tooling and fixtures have been made to replace the ones which had become unusable from wear and tear.

Figure 3 shows the niobium outer housings. The ports at the upper end of the cylinder are used for coupling and picking up RF power into/from the resonator. The beam ports are located at the lower end of the cylinders. Each outer housing assembly has seven electron beam welds. Figure 4 shows the loading arm and drift tube assemblies, made out of high RRR grade (>200) material. Each loading arm has two and each drift tube assembly has seven electron beam welds. The loading arm and drift tube form the inductive and capacitive part of the central conductor assembly respectively, which joins the outer housing through a niobium top flange.

Figure 3: Niobium Outer Housings.

In addition to the major assemblies shown in figures 3 and 4 machining of the niobium top flanges has started. Fabrication of the outer stainless steel vessels, which holds the liquid helium, has been completed. The stainless steel top flange of the resonator is being modified into a hemispherical dome to provide large buffer volume of liquid helium [7]. All the niobium-stainless steel flanges that provide the transition at the ports have been machined. SS bellows assemblies with appropriate end fittings for the same have been commercially procured, thermally shocked and pressure tested.

Figure 4: Loading Arm (below) and Drift Tube (top) assemblies.

The major assemblies shown in figures 3 and 4 are ready for electropolishing. Additional fixtures for this work have been made and the various acids required have been procured. As a quality control measure some critical welds will be radiographed before electropolishing is done. During the electropolishing work we plan to start the fabrication of the niobium slow tuner bellows. Niobium-copper explosion bonded material for the same has been received. Machining of the niobium-stainless steel open-end flanges, that provides the transition from the inner niobium housing to the outer stainless steel vessel at the slow tuner end of the resonator, will also be taken up during this period. We plan to complete all the fabrication work by the middle of this year.

RESONATOR REPAIRS

In addition to constructing resonators for the linac a variety of repairs on existing resonators have been successfully carried out. On several resonators the coupling and beam port transition flange bellows developed leak. A new design of the assembly has already been developed [3]. The leaking assemblies are machined out and replaced with the modified design. Prior to e-beam welding, the bellows as well as the complete assembly is thermally shocked and pressure tested.

The QWRs made for the first linac module had three coupling ports. Two of the ports were meant for coupling and picking up RF power into/from the resonator and the third port was kept for the VCX fast tuner system [8]. The present resonator control system in the IUAC linac, however, uses dynamic phase control, which has made the third port redundant. It has been blanked off with a niobium flange on the resonators in the first linac module. On some QWRs the transition bellows assembly on this port developed leak. They have been permanently closed, instead of replacing with a new bellows assembly, by e-beam welding a niobium blankoff.

On three resonators the upper cap on the drift tube got punctured. The resonators were cut open and the punctured caps have been replaced. Figure 5 shows one of the repaired drift tubes.

Figure 5: A repaired Drift Tube assembly.

SINGLE SPOKE RESONATORS

In addition to constructing resonators for the in-house programmes, a project to build two single spoke resonators of β=0.22, operating at 325 MHz, for the proton driver linac for Fermi National Laboratory (FNL) is being taken up [9]. Figure 6 shows a view of the proposed spoke resonator which has been designed by FNL. Preliminary assessment of the tooling and fixtures required for the construction has started. The actual fabrication work is expected to begin towards the end of the production of the QWRs.

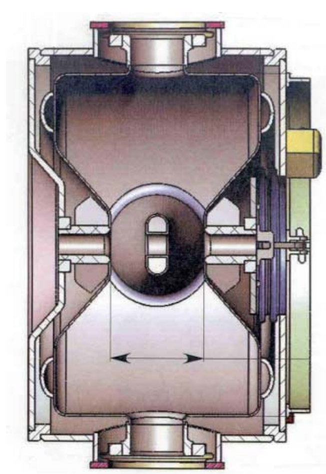

Figure 6: 325 MHz, β=0.22 Single Spoke Resonator.

CONCLUSIONS

The Superconducting Resonator Fabrication Facility at IUAC has been fully operational since July ‘2002. The facility is being used for constructing niobium resonators for the linac project. IUAC has successfully fabricated niobium quarter wave resonators and is currently in an advanced state of producing fifteen resonators for the second and third modules of the linac. One of the indigenously built resonators has been installed and tested in the rebuncher cryostat of the linac. Its online performance is inferior compared to the offline performance (4.5 MV/m @ 6 W). This could possibly be due to the slow cooling rate in the rebuncher cryostat, especially between 150 K and 80 K, which is known to produce Q-disease in niobium resonators. IUAC has also developed expertise in carrying out critical repairs on existing resonators. In addition to building resonators for the in-house projects construction of two single spoke resonators for FNL will also begin shortly.

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