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FABRICATION OF TESLA-SHAPE 9-CELL CAVITIES AT KEK FOR STUDIES ON MASS-PRODUCTION IN COLLABORATION WITH INDUSTRIES

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Abstract

The construction of the new Center-of-Innovation (COI) building started at KEK from 2014 for the studies of mass-production of Superconducting-RF (SRF) accelerators in collaboration with industries. The COI building is sitting next to the existing KEK-STF building and includes various SRF facilities like clean-room for cavity-string assembly, cryomodule-assembly facility, cryogenic system, vertical-test, cryomodule-test, input-coupler processing, cavity Electro-Polishing (EP) facilities, and control-room/office-rooms in the dimension of 80 m x 30 m. The purpose of these new SRF facilities is to establish a close collaboration between SRF researchers and industries in order to prepare for the upcoming small- and middle-scale SRF programs, and also large-scale future SRF projects, like ILC. This article reports the fabrication of four TESLA-shape 9-cell cavities for the commissioning of these new facilities the details of the new SRF facilities.

INTRODUCTION

KEK and several industry companies: Mitsubishi Heavy Industry (MHI), Hitachi, Toshiba, Mitsubishi Electronic, Kyocera, Fujikura, etc. obtained a new budget from "Ministry of Education, Culture, Sports, Science and Technology of Japan" (MEXT) in 2012. The title of new budget is "New Project for Creating a Market for EARTH-CLEANER Products in Collaboration with Industries and Laboratories / Universities". In the program of the budget, we proposed to produce new innovations to realize sustainable societies on the earth by the accelerator science in collaboration among laboratories, universities, and industries. In order to keep the earth sustainable, we need to solve the serious problems such as "pollution of the earth", "warming of the earth", "energy crisis", "natural resources shortage", etc. Here, the situation created the needs for "new energy network system", "integration of power plant and water/air cleaner" and so on, which clean the environment of the earth. The new project by the budget utilizes the Superconducting Accelerator and Quantum Beam Technology, and create a new market for these "EARTH CLEANER" products. Finally, the goal of the project is to challenge the realization of global/sustainable environment on the earth. After the proposal and budget were successfully approved, we started the construction of new SRF building at KEK, which is so-called Center-of-Innovation (COI) building. Various SRF facilities were planned to be installed in the COI building to realize the innovations to create the EARTH-CLEANER products. We started the construction of COI building at KEK from 2014 and finished the construction in January 2015.

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VARIOUS SRF FACILITIES IN COI BUIDING

Figure 1 shows the picture of the existing Superconducting Test Facility (STF) and new COI buildings, and the bird view of these two buildings at KEK.

Figure 1: The picture of STF and COI buildings and the bird view of these two buildings.

The new COI building includes various SRF facilities like clean-room for cavity-string assembly, cryomodule-assembly facility, cryogenic system, vertical-test, cryomodule-test, input-coupler processing, cavity Electro-Polishing (EP) facilities, and control-room/office-rooms in the dimension of 80 m x 30 m. The layout plan of these facilities in the COI building is shown in Figure 2.

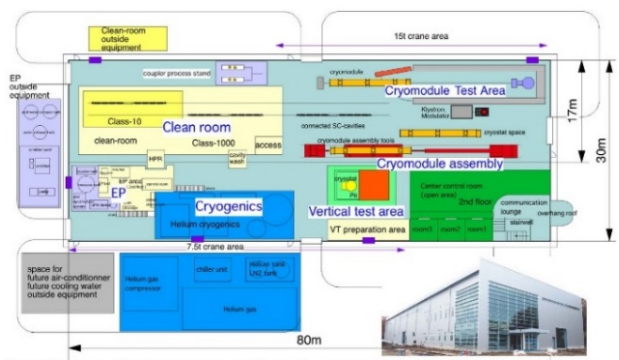

Figure 2: The layout plan of SRF facilities in the COI building.

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From January 2015, we started the installation of these SRF facilities in COI building. The current status of the installation is following.

Vertical Test Stand

Figure 3 shows the current status of Vertical Test (VT) stand in COI building. The cryostat was designed by KEK and Mitsubishi Heavy Industry (MHI) referencing the VT Cryostat of AMTF/DESY aiming at the mass-production of SRF accelerators, where the facilities of AMTF/DESY nowadays are fully utilized for the EURO-XFEL mass-production. The cryostat in COI building enables to perform the VT of four 9-cell cavities at once.

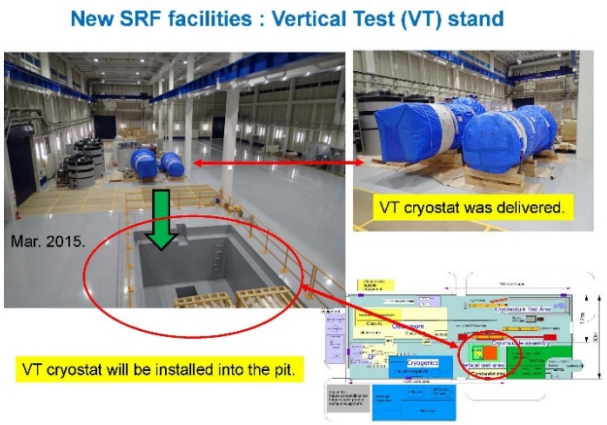

Figure 3: The current status of Vertical Test (VT) stand in COI buildings. The cryostat was already delivered.

Clean-room and Cryomodule Assembly Facility

Figure 4 shows the current status of clean-room and cryomodule assembly facility in COI building.

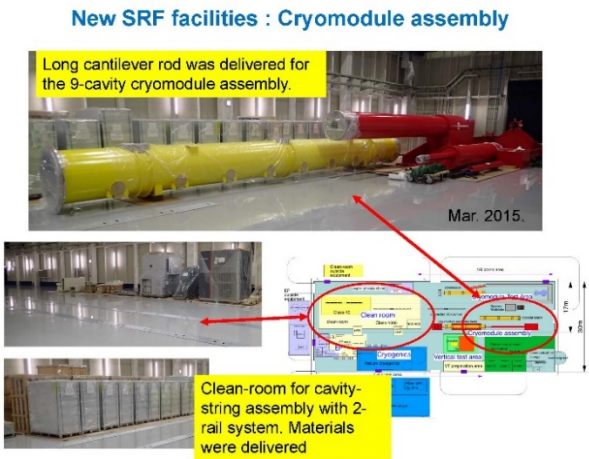

Figure 4: The current status of clean-room and cryomodule assembly facility.

The clean-room has two-rail system and each of rail enables to assemble a nine-cavity-string in the class-10 clean-room. The wall materials and ventilation equipment of the clean-room were delivered. The long cantilever for the cryomodule assembly with the nine-cavity-string was delivered.

Electro-Polishing (EP) Facility

Figure 5 shows the EP bed of the EP facility in COI building. The EP bed is compatible with both Horizontal and Vertical EP setups where the EP bed can rotatable and a motor for cathode rotation is equipped. This enable to compare the Horizontal and Vertical EP processes directly in one facility. In addition to this EP bed, the waste tanks were delivered to install outside of CIO building.

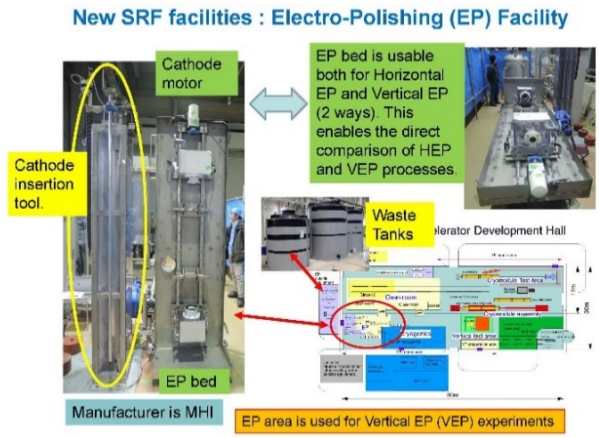

Figure 5: The current status of Electro-Polishing (EP) facility in COI buildings. EP bed and waste tanks were delivered.

Cryogenic System

Figure 6 shows the current status of cryogenic system. The He refrigerator (250 L/h and 500 W at 4.4 K) and He compressor parts were delivered. The cryogenic system supplies liquid He to the VT cryostat and cryomodule high-power test facility which is beside the cryomodule assembly area. The He compressor parts will be assembled in a small building outside of COI building.

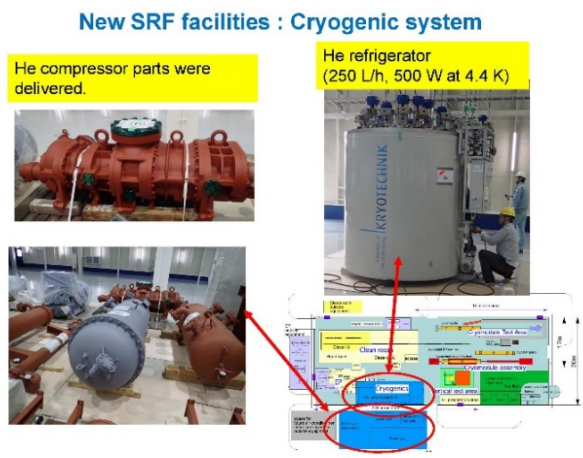

Figure 6: The current status of cryogenic system. The He refrigerator and He compressor parts were delivered.

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Control Room and Offices

The control-room and offices are located in COI building which are shown in the green area in Figure 2. The area has two-floor structure. The control-room and offices for researchers are located on the 2nd floor and a meeting room and offices for industry staff are located in 1st floor. The control-room has large windows facing outside and also the experimental hall to see all the facilities from the height of 2nd floor. The offices for industry staff are equipped with card-key system where the intellectual properties of each industry company would be protected.

FABRICATION OF TESLA-SHAPE 9-CELL CAVITIES

The COI building is designed to be compatible with productions and R&D activities of all types of SRF accelerators like small table-top light-sources, middle-size ERL and/or XFEL programs, and also large-scale projects like ILC. This is the reason why all the SRF facilities in COI building are designed referencing EURO-XFEL mass-production facilities that already successfully start the production of more than 800 cavities and cryomodule assembly. Subsequently, we need the TESLA (EURO-XFEL) type 9-cell cavity, so called TESLA-shape cavity, for the commissioning of these facilities. We ordered four TESLA-shape cavities to MHI and Toshiba and both companies delivered the cavities successfully. Figure 6 shows the pictures of these cavities.

Figure 6: The pictures of four TESLA-shape 9-cell cavities which were fabricated by MHI (upper picture) and Toshiba (lower picture).

JAPANESE HIGH PRESSURE GAS SAFETY ACT

The fabricated four TESLA-shape cavities are not complying with Japanese High-Pressure Gas (J-HPG) safety act, because these cavities are only used for the commissioning of new SRF facilities and will not be used in any operational accelerator. But if one install cavities into operational accelerators in Japan, one must fabricate cavities complying with J-HPG safety act. The procedures of J-HPG safety act involves several steps before and during the fabrication of cavities. The first step is the simulation analysis to confirm the strength of liquid-He pressure-vessel. The following steps are the declarations of welding details of Nb cavity and Ti jacket to the authority. In addition, one must perform series of pressure tests and report the results to the authority. If we might host international projects like ILC, we will import significant numbers of cavities from foreign venders for the installation into operational accelerators. In such cases, the procedures of J-HPG safety act are mandatory even for foreign venders. Consequently, KEK should guide the procedures to foreign venders for smooth installation, and then KEK should once go through these procedures with TESLA-shape cavity. We started the first step, simulation analysis of these procedures with TESLA-shape cavity, in collaboration with Toshiba. The preliminary results of stress distribution simulation-analysis showed that the TESLA-shape cavity might comply with J-HPG safety act.

EXPERIMENTAL PLAN BY USING TESLA-SHAPE CAVITY

It will take more than one year to complete the assembly of facilities in COI building. The four TESLA-shape cavities can be used for some R&D experiments until the completion of COI facilities. In the end of 2014, one TESLA-shape cavity was already sent from KEK to Cornell University (F. Furuta and G. Hoffstaetter) to use it for Vertical EP (VEP) R&D experiments. Bulk BCP (total 100 um, flipped cavity after 50 um etch) was done at Cornell University for the surface preparation before VEP experiments. Degassing/annealing at 800 ^{0}C for 2 hours followed. Currently the 9-cell cavity is waiting for VEP R&D experiments.

SUMMARY

The construction of new Center-of-Innovation (COI) building was completed in January 2015. Various components of new SRF facilities were delivered in the COI building. TESLA-shape cavities are needed for the commissioning of these SRF facilities. The fabrication of four TESLA-shape cavities were ordered to industrial venders (MHI and Toshiba) and these cavities were successfully delivered. We will go through the procedures of Japanese High-Pressure Gas (J-HPG) safety act with TESLA-shape cavity to guide foreign venders for international projects like ILC. Simulation analysis of stress distribution in TESLA-shape cavity was done in collaboration with Toshiba. The preliminary results show the TESLA-shape cavity might comply with the J-HPG safety act. One TESLA-shape cavity was sent to Cornell University for the Vertical EP R&D experiments.

ACKNOWLEDGMENT

We deeply appreciate the remarkable leadership of the former Director General of KEK, A. Suzuki, to organize universities, industries and laboratories for the approval of the program and budget.