

THE ASSEMBLY EXPERIENCE OF THE FIRST CRYO-MODULE FOR HIE-ISOLDE AT CERN

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Abstract

The HIE ISOLDE project aims at increasing the energy of the radioactive ion beams of the existing REX ISOLDE facility from the present 3 MeV/u up to 10 MeV/u for an A/q up to 4.5 [1]. The upgrade includes the installation of a superconducting linac in successive phases, and ultimately comprising two low- β and four high- β cryo-modules. The first phase involves the assembly installation and test of two high- β cryo-modules, each housing five high- β superconducting cavities and one superconducting solenoid, aligned within tight tolerances. Following design and procurement of cryo-module components for 2 units, the first unit is now being assembled at CERN, in a dedicated facility including class100 (ISO5) clean rooms equipped with specific tooling. The assembly is foreseen to be complete and the cryo-module delivered to the beam-line in May 2015. In this paper, we present the assembly of the first unit, including the methodology, special tools, assembly procedures and quality assurance aspects. We report on the experience from this first assembly, including tests results, and present prospects for the next-coming cryo-module assemblies.

INTRODUCTION

The decision to implement a major upgrade [2] of the energy and intensity of the existing ISOLDE and REX-ISOLDE radioactive ion beam facilities at CERN requires the replacement of most of the existing ISOLDE post-acceleration equipment by a superconducting linac based on quarter-wave RF cavities housed together with superconducting solenoids in a series of four high- β and two low- β cryo-modules. The design and component procurement phases of the project complete for 2 high- β cryo-modules, CERN is now engaged for the first time in the assembly of cryo-modules, featuring a common insulation and beam vacuum, requiring, to preserve RF cavity performance, the installation of a purpose built ISO5 quality clean room and associated infrastructure. The assembly of the first high- β cryo-module started in late August 2014 and now at end April 2015 is completed. Although in all respects it is clearly a prototype, this first unit is destined for installation onto the HIE-ISOLDE beam-line in May 2015 and will there be subjected to full functional testing.

THE CRYOMODULE ASSEMBLY

The complete high- β cryo-module assembly is shown in Fig.1. The components and sub-assemblies comprising the cryo-module their specific characteristics and expected performance are detailed in [3].

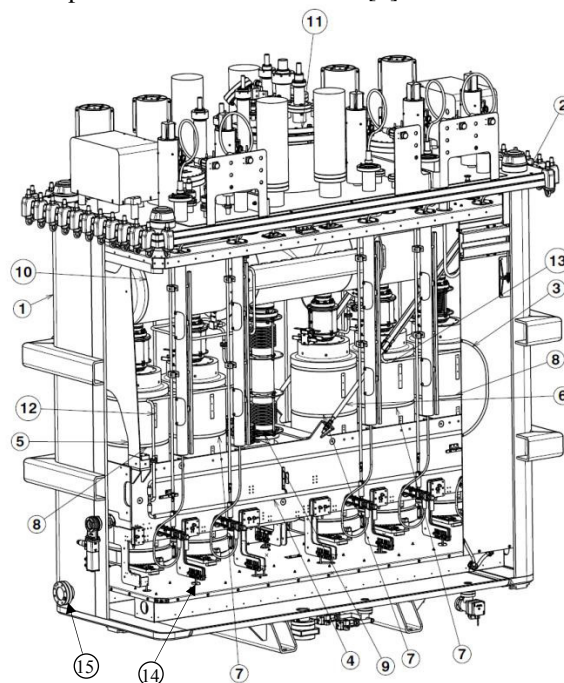


Figure 1: The complete HIE-ISOLDE high- β cryo-module; 1 Vacuum vessel lower box, 2 Vacuum vessel top plate assembly, 3 Thermal shield lower box, 4 Support frame, 5 Suspension end plate, 6 Tie-rod, 7 Inboard cavity, 8 Outboard cavity, 9 Down tube to solenoid, 10 Helium vessel, 11 Chimney assembly, 12 Support frame cooling supply, 13 Support frame cooling return, 14 Mathilde targets, 15 Mathilde viewport.

A vertical assembly, suspended from the mobile frame (see Figure 3) and essentially built from top downwards is implemented. The complete cryo-module assembly process has been separated into 20 sub-assembly stages, in a sequence imposed by the cryo-module design and by the tooling characteristics and featuring the installation of the RF cavities at the latest possible stage in order to minimize the risk of their contamination.

THE ASSEMBLY FACILITY

Shown in Fig 2, the cryo-module assembly facility covering a floor area of 130 m² encompasses a central unloading area and 2 clean rooms; in the foreground an ISO 5 vertical flux of volume 4 × 4 × 2.5 m³ for component and sub-assembly preparation and in the rear ground an ISO5/ISO7 horizontal flux 10 × 5 × 5 m³ equipped with specific tooling for the cryo-module assembly.

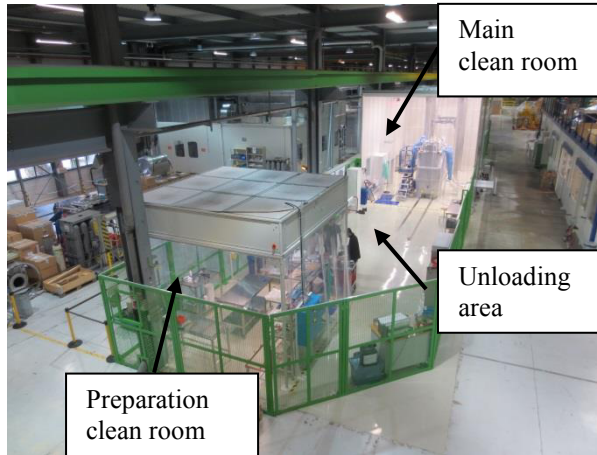


Figure 2: The HIE-Isolde cryo-module assembly facility.

Specific Assembly Tooling

Resources were invested in clean room compatible tooling designed to be easy to use and offering intrinsic precision, to unburden the assembly staff and allow them to focus fully on the assembly steps in hand. A schematic view of the specific assembly tooling in the main clean room is shown in Fig. 3. Stainless steel rails are set horizontally into the floor to within 0.5 mm over their 15 m length. Two rolling vehicles, one for general purpose use and one specifically designed for the transport and insertion of the RF cavities and the solenoid have been built in stainless steel conforming to clean room requirements. These vehicles permit the controlled transport of cryo-module components from the loading area to any station in the main clean room but in particular to final precise location under a 4-post tower frame installed in the rearmost ISO5 part. Each post of the tower frame is fitted with an electrically motorised clean-room compatible linear movement. A mobile frame, installed inside the tower frame is linked at each of its corners to one of the linear movements. Electronic synchronisation of the 4 linear movements allows the mobile frame, while being maintained horizontal to within 0.5 mm to be displaced at pre-programmed speeds of 800 mm/min or 20 mm/min and inched to the required working height to within 0.6 mm anywhere over a range of 4.5 m while carrying a maximum load of 2.5 tonnes.

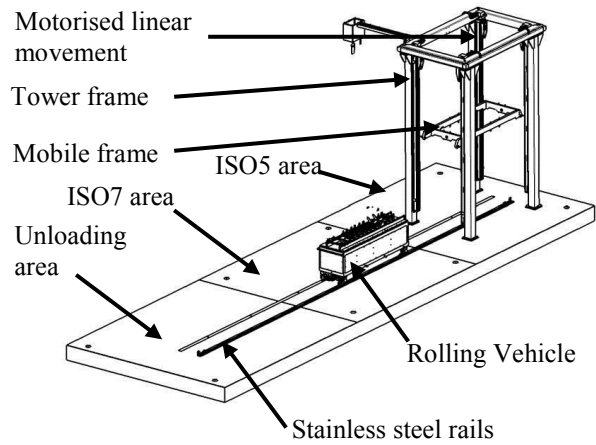


Figure 3: The specific assembly tooling.

WORK ORGANIZATION

One cryo-module contains more than 10000 parts grouped under more than 500 references going in size from sub-millimetre dimensions to four cubic meters and weighing 2.5 tonnes. The assembly involves a sequence of non-repetitive operations each requiring individual planning. Success depends heavily on a logistics platform, of floor area 190 m² situated in an adjacent building, for checking, cataloguing, cleaning, conditioning, storage and management of incoming and outgoing cryo-module components, sub-assemblies and elements of assembly tooling. This space was also used to make a blank assembly of the more complex sub-assemblies. To keep track of stock and movements, a specific database was developed using Access software.

Methodology

A work-flow diagram is shown in Fig 4; all activity focuses on maintaining a smooth effective flow of work on the main assembly minimising man-hours spent in and contamination of the main clean-room.

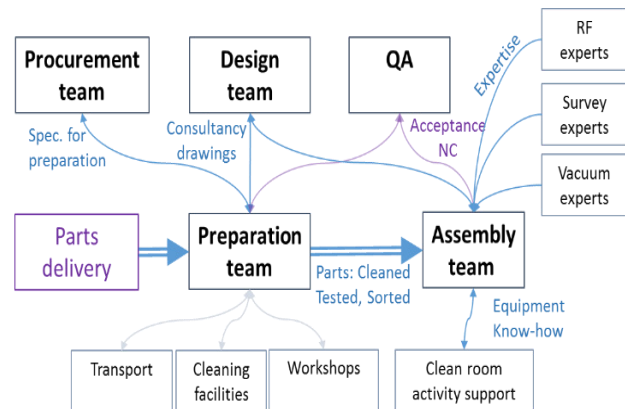


Figure 4: Work organization and flow.

Immediate activities were planned day to day on a half day basis while ensuring two week's advance preparation and notice to intervene to external experts from vacuum, large scale metrology survey, RF and quality assurance.

Assembly work progress was reported directly from the worksite on a daily basis and once weekly at planning and schedule meetings. Two full time staff managed logistics and 4 operated, 2 in each of the clean rooms.

QUALITY ASSURANCE

Assembly Procedures

The work to be achieved at each stage is detailed in assembly procedures that make reference to component drawings, assembly drawings, and measurement and test protocols. These procedures have been reviewed and refined through several iterations during the assembly of the first cryo-module.

Quality Assurance Tests and Results

Quality assurance tests were planned at key stages throughout the assembly. Leak tests and residual gas analyses allowed early stage identification of leaks and sources of contamination. Staged electrical tests were performed on each set of instrumentation installed. Survey intervened on the clean room infrastructure, for geometrical follow-up, and validations, deformation tests, assembly follow-up, alignment and monitoring. Survey campaigns and intermediate adjustments ensured rapid final alignments with the RF cavities in place to reduce risk of particulate contamination. RF ancillaries were tested at warm at the end of the assembly, as were RF cables losses, Q_{ext} (external quality factor) of couplers and pick-ups. The coarse tuning range was adjusted to be ~30 kHz with the target cavity frequency at warm locating within 10 kHz around the middle position. Measurements confirm the integrity of the installed equipment.

RGA testing identified one source of pollution inside the cavity tuner feed through bellows, this was mitigated sufficiently through re-cleaning of the bellows. At the pressure level given by the short pump down and water outgassing coming from the instrumentation (7.3×10^{-5} mbar after 20 hours) no contamination was observed. The leak tightness of the cryo-module 70 K circuits and 4.5 K circuits before cavities installation was measured below 2×10^{-10} mbar.l/s at room temperature.

The RF cavity apertures have been aligned horizontally and vertically to within 0.1 mm with respect to an axis coincident with the solenoid axis. After cryo-module installation and cool down, the active components aligned on this common axis may be monitored optically and if needed, repositioned with respect to the beam-line using the Mathilde [4] system.

Non Conformities

Related to the assembly, 64 non-conformities were raised, with 23.4% related to instrumentation, 21.9%, to the thermal shields, 10.9%, to the support frame, 9.4%, to the vacuum vessel and 34.4% on others. Three further non-conformities were opened for leaks detected during tests, 2 were opened because of activity outside standard procedures and 22 defect reports detailed the need for tooling improvements.

EXPERIENCE AND LESSONS LEARNED

Work Organization

A fluid and effective main assembly depends on forward planning of at least 2 weeks and on preparation of parts and sub-assemblies for upcoming activities. Rapidly, the ISO5 4mx4m clean room became 80% dedicated to preparation work. A complete set of test and measurement equipment was obtained and preconditioned in advance for clean-room use. The ability in a clean room to address situations ranging from mechanical assembly to verification of instrumentation and cable looms and to participate fully in problem solving requires highly experienced assembly staff and project- dedicated drawing office and workshop personnel. Although the project schedule precluded a full blank assembly of the complete cryo-module, such assemblies were added to the basic procedure for critical stages to identify problems at the earliest opportunity. Investing in high quality precise motorized tooling has afforded repeatable results enhanced quality and a reduction in the assembly time.

Components and Assembly

Having available from the start, components and sub-assemblies for 2 cryo-modules together with a full set of spare fasteners, flanges, bellows etc. ready at an early stage has afforded precious flexibility for in-work problem solving when faced with non-conformities.

Most structural surfaces in vacuum were electro-polished or brushed which simplified and shortened their cleaning in the clean-room. For components for project phase 2 (cryo-modules 3 and 4), mechanical brushing of stainless steel will also be invoked on all external surfaces. Fears of metallic particle release during tightening of silver plated stainless steel fasteners lead to the decision instead to implement the Kolsterizing® technique to avoid galling of dry unlubricated stainless steel. Kolsterising is effective if both parts are treated but leads to a highly nonlinear clamping behaviour when closing flanges. Particle release when tightening Kolsterised fasteners was much higher than expected. Final results of these tests, may motivate a decision to return to silver plated fasteners and/or where applicable the use of CuNi₂Si bronze nuts.

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