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ON-SITE TRANSPORT AND HANDLING TESTS OF CRYOMODULES FOR THE EUROPEAN SPALLATION SOURCE

F. Schlander*, A. Bignami, N. Gazis, European Spallation Source ERIC, Lund, Sweden

Abstract

The cryomodules for the superconducting Linac of the European Spallation Source ESS are now arriving in a steady stream and the long-distance transport requirements are well understood. For the on-site transportation, handling and storage, several challenges have risen, including the intermediate storage of cryomodules before testing and/or installation. In comparison to the long-distance transports, the cryomodule on-site transports and respective handling until installation take place with specialised and limited transport protection. This requires additional measures and tests of those handling steps with extended diagnostics, to make sure that handling and transport refrains from damages on the last mile. Those handling procedures and executed tests will be described in this contribution.

INTRODUCTION

The accelerator of the European Spallation Source will accelerate protons to 2.0 GeV at a pulse current of 62.5 mA. The main portion of the accelerator consists of in total 43 cryomodules containing superconducting cavities. For the lowest energy, 13 cryomodules, containing 2 double-spoke cavities each, are provided via in-kind by IJCLab in Orsay, France [1]. Further there are 9 medium-beta cryomodules, containing 4 6-cell elliptical cavities each, and 21 high-beta cryomodules, containing 4 5-cell elliptical cavities each. Those cryomodules are provided via in-kind from CEA Saclay IRFU, while the installed cavities are in-kind contributions from INFN LASA Milan for the medium-beta cavities, and the high-beta cavities from ASTeC, STFC Daresbury [2–4]. As cryomodules are very delicate objects, the transport and handling of those needs to be done with great care. For the road transport between the laboratories, lessons learned from other projects [5, 6] were taken into consideration and all of the approximately 15 transports to ESS up to now were successful. At ESS the cryomodules arrive at different locations for either temporary storage or testing. After this, the cryomodules will have at least another transport, although only on site, transport and handling tests with extensive diagnostics mounted on the cryomodules have been carried out, and the results with be described in the following sections. An overview of the different locations and routes on the ESS site is shown in Fig. 1.

MODULE PREPARATION

After the arrival at ESS the configuration of the elliptical cryomodules is changed from transport configuration to test and tunnel configuration. This results in removal of all transport protection (see Fig. 2 for explanation), which makes the contents of the cryomodules much more sensitive, as the cavity string, the thermal shield and the space frame are no longer blocked in their movement .

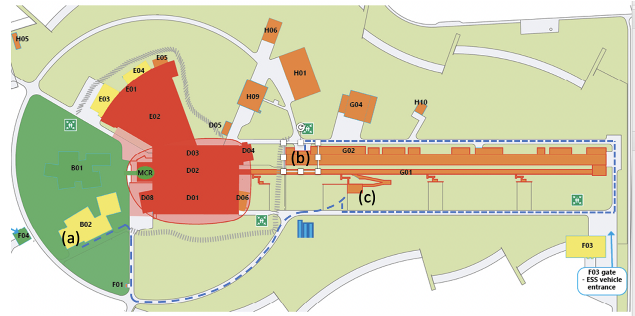

Figure 1: Site overview of ESS with cryomodule storage (a,b), test (b) and installation locations (c).

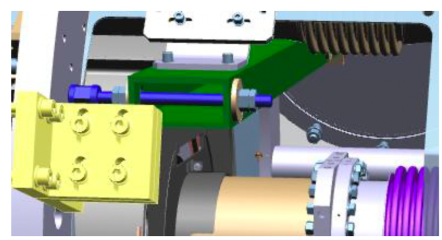

Figure 2: Transport protection inside the elliptical cryomodule. In green: a bar to block movement of the cavity string with respect to the space frame, in silver above: fixation of the thermal shield, yellow: blocking of the space frame fixed at the vacuum vessel.

The components mentioned and the installed diagnostics is shown in Fig. 3. For diagnostics, 4 enDAQ S3-D16 vibration sensors (shock loggers) and a combination of monoaxial (Mod. 602D01, 100 mV/g) and triaxial (Mod. 604B31, 100 mV/g) PCB piezo accelerometers have been used on the medium beta prototype cryomodule CM0 [7]as the test cryomodule.

For the spoke cryomodules no changes are done from the reception until the positioning in the tunnel. The diagnostics mounted are 2 PCB Mod. 356B18 and the locations are shown in Fig. 4

MEASUREMENTS

For the spoke and elliptical cryomodule transport tests different routes to the tunnel entrance were chosen according to their storage- or test location, as shown in Fig. 1.

* felix.schlander@ess.eu

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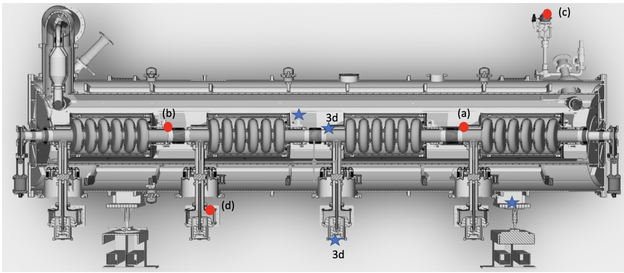

Figure 3: Elliptical cryomodule with transport diagnostics installed - red: shock loggers, blue: either 1-axis sensors or 3d sensors.

Figure 4: Spoke cryomodule with transport diagnostics installed.

Elliptical Cryomodule

From the postprocessing of the data collected by the accelerometers, a Power Spectral Density (PSD) in the frequency domain has been calculated, considering the sensor on the leg as reference. In Fig. 5 the outcome of the measurements performed during the transportation of the cryomodule along the accelerator tunnel is depicted, taking into consideration the axis parallel to the one of the cavities inside.

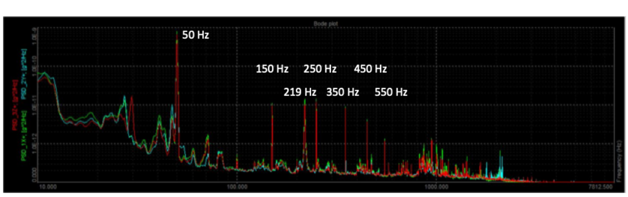

Figure 5: PSD of tunnel transportation on cavity axes.

The 4 EnDAQ units were taking measurements during the complete test which lasted one working day for bringing the module from the Test Stand 2 area to the tunnel and back. The results are shown in Fig. 6. No events of concern have been found except on the valve actuator. But those high accelerations could be traced back to the opening and closing of the roof of the truck, where the reinforcement bars of the roof have touched the EnDAQ unit.

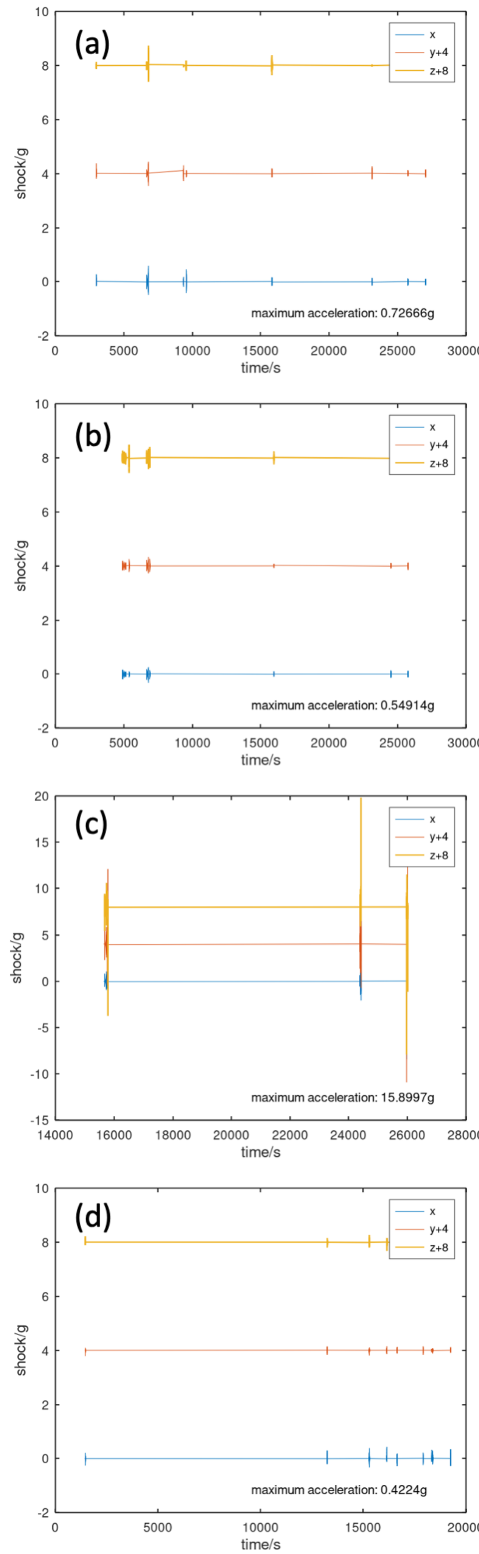

Figure 6: Results of EnDAQ units, showing only the 10 largest shocks each. With (a) (b) are locations on the cavity string, (c) on one of the doorknobs and (d) on one cryogenic valve as depicted in Fig. 3.

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Spoke Cryomodule

The spoke cryomodule CM02 underwent a test installation during winter, which also has been used to test all the handling and site transportation. The route taken is shown in Fig. 1. As for the elliptical, an analysis both in the time and the frequency domain have been performed. As shown in Fig. 7, the time domain results show some high values of acceleration (10g) in correspondence with the lifting and lowering of the object on its support. It is an instantaneous value that catches the moment when there?s the full release of the impact energy due to a hard contact of two stiff object, probably magnified by the high sample rate (20k samples per second). The Root Mean Squared (RMS) value already reduce the peak value (3g), see Fig. 8. Further investigation with a reduce sample rate and different lifting condition is required to affirm with more sureness that no possible harm can be done to the cryomodules during transportation.

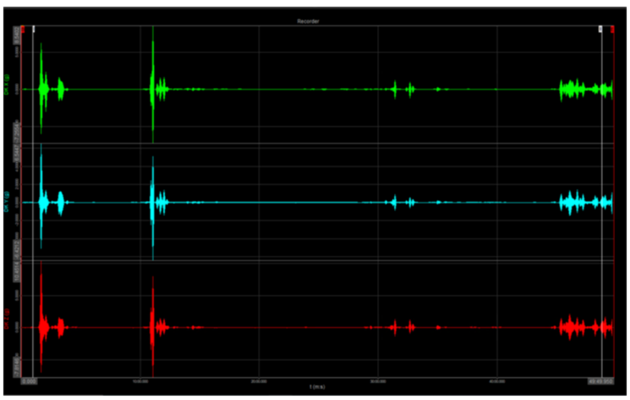

Figure 7: Time Domain results from the DK sensor on the three axes (Real Values).

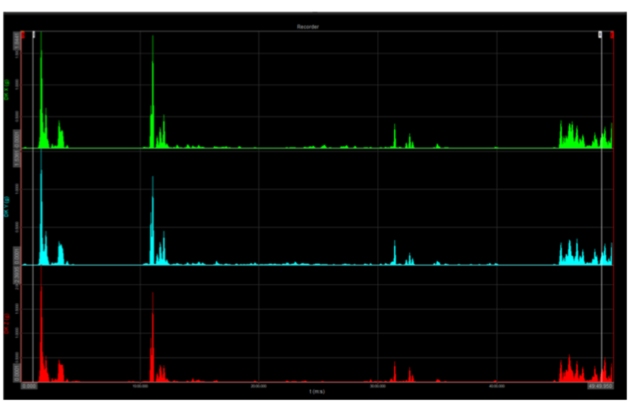

Figure 8: Time Domain results from the DK sensor on the three axes (RMS).

SUMMARY

The handling and transport of cryomodules on site is a complex task, since they are in their final configuration for tunnel installation and thus more sensitive to acceleration and shocks. ESS has exercised this for an elliptical and a spoke cryomodule with monitoring the accelerations that occurred and found that the handling procedures are appropriate.

ACKNOWLEDGEMENTS

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