

THE CRYOMODULE TEST STANDS FOR THE EUROPEAN SPALLATION SOURCE

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Abstract

The linear accelerator for the European Spallation Source (ESS) contains 13 cryomodules with 26 double-spoke cavities and 30 cryomodules with 120 elliptical cavities. Before installation, these cryomodules will be tested in two dedicated test facilities: Test Stand 2 (TS2) at the ESS site in Lund and the FREIA Laboratory at Uppsala University for the elliptical and spoke cryomodules respectively. All cryomodules will go through their Site Acceptance Tests (SAT) on these test stands. Here we describe the details of the test stands which each consist of a bunker, cryoplant and radio-frequency power sources.

INTRODUCTION

The European Spallation Source (ESS) is currently under construction in Lund, in southern Sweden. The superconducting section of the linear accelerator consists of three parts; 26 double-spoke cavities at 352.21 MHz gathered in 13 cryomodules, 36 medium beta elliptical cavities at 704.42 MHz gathered in 9 cryomodules and 84 high beta elliptical cavities also at 704.42 MHz gathered in 21 cryomodules [1]. These cavities allow the acceleration of the beam from 90 MeV to 2.0 GeV. The cryomodules have to be tested in dedicated test facilities before installation in the ESS tunnel. TS2 in Lund is dedicated to the tests of the medium and high beta elliptical cryomodules and the FREIA Test Stand at Uppsala University, Sweden, is dedicated to the tests of the spoke cavity cryomodules. All cryomodules will go through their Site

Acceptance Tests (SAT) on these dedicated test stands which will each consist of a radiation protection (RP) bunker, a test stand cryoplant and radio-frequency (RF) power sources. Both test stands will allow the SAT of cryomodules with full cryogenic load at the final operating temperature and with full RF load on all cavities in parallel.

TEST STAND 2

TS2 [2] is located at the ESS site in Lund, located in the contingency area of the klystron gallery building, also referred to as the Gallery Technical Area. TS2 consists of a radio-protection bunker with the same cross section as the accelerator tunnel, a test stand cryoplant and a modulator and two klystrons as RF power sources. The test stand will provide facilities for testing the elliptical cavity cryomodules of both varieties: medium beta and high beta.

General Layout

The overall layout of TS2 is shown in Fig. 1. Two rows of together 24 electrical racks are placed in the test stand to include the control and instrumentation equipment for RF, cryogenics, vacuum, cooling water, timing system, motion control, Personnel Protection System (PSS) and Oxygen Deficiency Hazard (ODH) detectors. A number of spare racks will allow the test stand to be flexible and expandable.

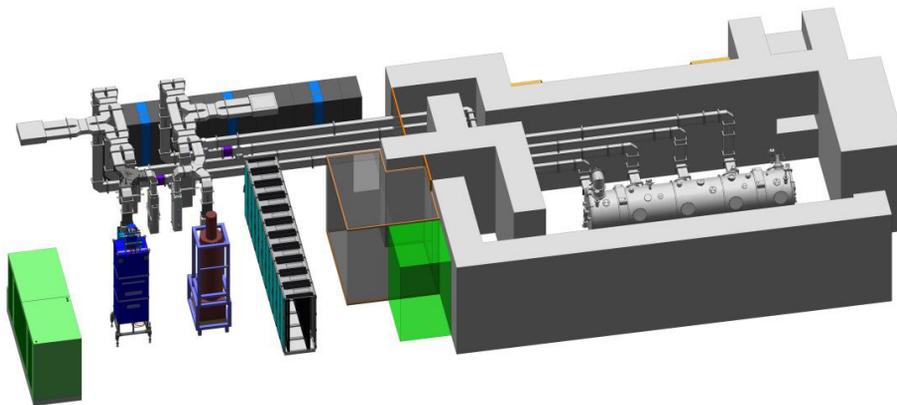


Figure 1: Layout of the Test Stand 2 (TS2) at ESS, Lund.

RP Bunker

The main function of the bunker is to protect the surrounding area from x-rays produced during the cryomodule tests [3]. It consists of 1200 t of heavy, magnetite loaded concrete, arranged to form 1 m thick walls all around the cryomodule, while allowing services such as cryogenics, RF and cabling to enter through chicanes. A personnel access chicane and a full width access door for the cryomodules are also part of the bunker.

Cryoplant and Cryogenic Distribution

The test stand cryoplant TICP is composed by a liquefier coldbox, a recovery system and an external purifier. It will serve the following tasks:

- Provide cooling for TS2 at 2K and 40K with a liquefaction rate of 6 l/h.
- Provide liquid helium for ESS' neutron instruments and sample environments with a liquefaction rate of 7500 l/month.
- Recover, purify and manage helium at the facility.

Although the TICP will only be used for continuous cryomodule testing for the first few years, this operation defines the plant's design [4].

The cryogenic distribution system is dedicated to transferring cooling power from the TICP to the ESS elliptical cryomodules under their site acceptance tests in the test stand bunker. The system includes a cryogenic transfer line (CTL), one valve box and four auxiliary process lines. Its layout is shown in Fig. 2.

The CTL runs from the TICP cold box in the cold box building to the test stand bunker placed in the klystron gallery. The line is a vacuum insulated multichannel line and its vacuum jacket houses four cold process lines, thermal shield, supports and thermal compensation system. The cryoline ends in the test stand valve box, in which four branch process lines connect to the cryomodule cold circuits.

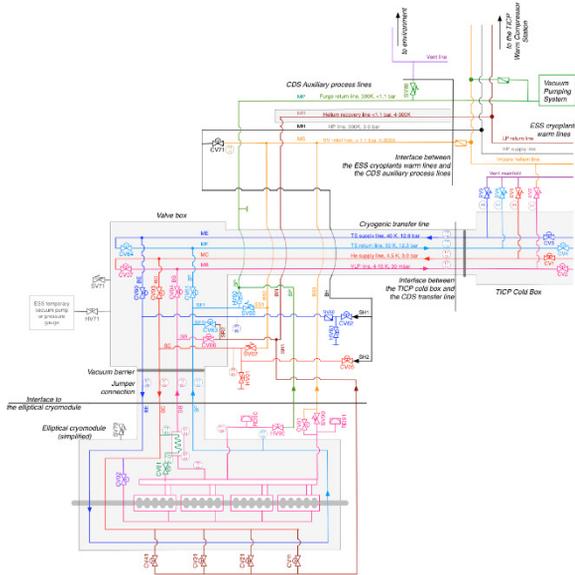


Figure 2: Layout of the cryogenic distribution of TS2.

RF System

The RF system at TS2 consists of RF sources and conditioners (klystrons and modulator), the RF distribution system and the low level RF (LLRF), shown in Fig. 3.

TS2 will power two klystrons from one modulator, one klystron per two cavities. The modulator will convert electrical power to the klystrons' cathodes from a standard low voltage distribution grid to an electrical pulse of 1 MW at the accelerators pulse frequency of 14 Hz. The klystrons will convert the pulsed power coming from the modulator to radiofrequency waves at 704.42 MHz.

The phase and amplitude of the electrical field in the cavity will be controlled by the LLRF system controls using a PI-controller [5].

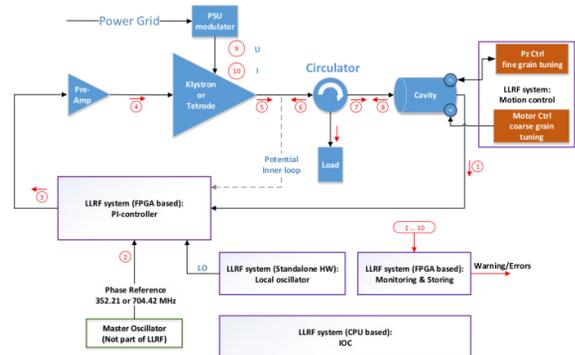


Figure 3: Block diagram of the LLRF system.

Commissioning

The test stand will test both medium beta and high beta cryomodules, to be installed in the linac. In order to commission all of the involved systems, a prototype cryomodule called Elliptical Cavity Cryomodule Technical Demonstrator (ECCTD) and containing more instrumentation than the series cryomodule [6] will be placed in the test stand during its commissioning phase.

FREIA TEST STAND

The FREIA Test Stand is located at the FREIA Laboratory of Uppsala University. Like TS2 it consists of a radio-protection bunker, a test stand cryoplant and RF power sources [7]. In addition, it has a horizontal cryostat HNOSS [8] for testing of individual cavities with or without power coupler. The test stand is adapted for the double-spoke cryomodules which are shorter than the elliptical cavity cryomodules and are operated at 352.21 MHz. The test stand allows testing of cryomodules with full cryogenic load at the final operating temperature and with full RF load on all cavities in parallel.

General Layout

The general layout of the FREIA test stand is shown in Fig. 4. The cryomodule and HNOSS share the same bunker, RF stations and cryoplant. The RF stations and cooling water plant are located on one short side of the bunker while the cryoplant is located on the other short side. The control room is facing the long side of the bunker.

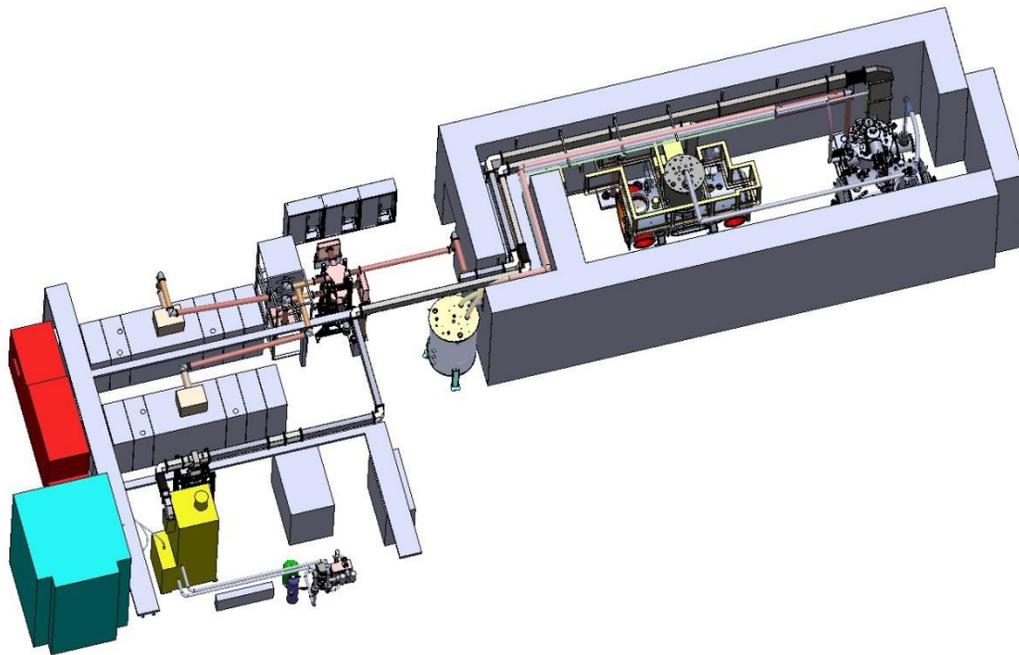


Figure 4: Layout of the FREIA Test Stand at Uppsala University.

Cryoplant and Cryogenic Distribution

The cryoplant is a commercial liquefier with a capacity of 140 l/h [8]. Liquid nitrogen is used for pre-cooling of the cryoplant and for cooling the thermal shield of the cryostats. The liquefier is connected to a 2000 l storage dewar from which a transfer line connects to the bunker. A cryogenic interconnection box inside the bunker is used to share the helium and nitrogen cryogen flow between HNOSS and cryomodule.

A sub-atmospheric pumping system is used to reach 2K temperatures in the test stand by lowering the pressure of the liquid helium bath. The pumping line is connected through a water filled cold gas heater.

RF System

The high power RF system consists of two tetrode based 352 MHz, 400 kW amplifier stations [9]. They are prototypes for the ESS accelerator developed by Uppsala University and industry and can provide full power, pulse length and repetition rate for testing double-spoke cavities according to ESS specifications.

The RF amplifiers can be operated in self-excited loop or in signal generator driven mode. The self-excited loop is typically used for the conditioning of the cavity package. An automatic conditioning system is under development in combination with a protection system based on vacuum pressure, RF arcing and electron emission current.

Control and Measurement Systems

Most of the sub-systems are controlled by vendor supplied systems. An overall control system has been developed based on EPICS to combine these local sub-systems and archive the data [10]. The RF conditioning and measurement system has been developed in LabVIEW.

Commissioning

The cryoplant, RF systems and auxiliary systems have been commissioned with help of the HNOSS cryostat and a first prototype double-spoke cavity with power coupler [11]. The complete test stand will be commissioned during Fall 2017 with a prototype double-spoke cryomodule and its valve box. This will be a prototype set-up identical to the set-up foreseen in the ESS accelerator tunnel. The first series cryomodule is expected mid-2018.

CONCLUSION

Considerable progress has been made with the preparation of the cryomodule test stands for the superconducting part of the ESS accelerator at ESS Lund and Uppsala University. Both test stands will be ready for operation in time for the first series cryomodules arriving in 2018.

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