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Appendix 1

Technical Specifications

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1. Introduction

The delivery consists of a complete pulsed raster scanning system for the European Spallation Source (ESS), located in Lund, Sweden. The first delivery will be a 2-magnet pre-series, to be followed be the full 8-magnet production series. Both these systems are considered complete in the sense that all necessary power supplies, cables, ceramic vacuum chambers, system performance monitors, support stands, and local control systems are included in the order.

The raster system generates pulsed magnetic field waveforms acting in both the horizontal (H) and vertical (V) direction with 4 magnets acting in each direction. By maintaining a H-V waveform frequency ratio differing from unity, the proton beam centroid follows a Lissajous-like displacement pattern during the raster pulse.

A descriptive list of system parameters can be found in the following, whereas a quantitative list of minimum requirements are found in Table 1-Table 3 at the end of this document. In general, the parameters mentioned in this document are considered minimum requirements, emphasized by the wording "shall". The wording "could" refers to suggestions and not actual requirements.

The systems must comply with all harmonised European standards as well as details regarding appropriate EMC regulations.

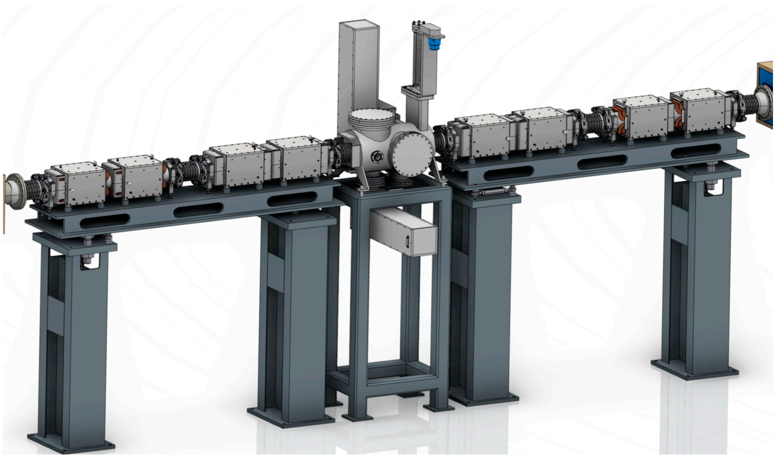

Figure 1: A drawing of how the full ESS raster system could be built, featuring 8 raster magnets in total. It should be noted that the central diagnostics chamber and support are not part of the package.

2. Detailed specifications

2.1 Magnetic

The fast magnets for ESS shall be made from materials with a frequency response suitable for a triangle magnetic field waveform up to 40 kHz fundamental frequency. Each individual raster magnet shall be equipped with a suitable Bdot pickup coil to enable monitoring of the produced field waveforms.

2.2 Electrical

The electrical system shall be built according to normal modern standards within the accelerator business. The systems shall apply to all normal European standards.

A basic separation between power and signal cables shall be provided.

Each magnet shall have its coils connected internally on the magnet with only two terminals (+ and -) on each magnet for connections of the external power leads.

Enclosure covers shall only be removable with use of tools. Any high voltage (greater than 50 V dc) shall be shielded.

2.3 Timing

Timing event receivers (existing hardware) will generate independent timing signals as input for the power supplies. This timing hardware is delivered by the ESS. The electrical standard shall be LEMO serial 00 connectors and TTL edge sensitive signals. The raster supplies shall generate waveforms that are phase-locked to these timing signals.

2.4 Control system and regulation

The supplies shall be able to operate in local and remote mode. In local mode, the supply shall be controllable via the front panel.

Control and monitoring of the supply in remote mode shall be made via Ethernet and TCP/IP.

An isolated output showing the Bdot signal measurement (0-10V) shall be available from all power supplies.

The ESS timing event receivers broadcast the current accelerator operational mode (e.g. beam energy). This information shall be used to configure the raster supplies.

Each raster supply shall provide an OK/NOK state signal for the ESS Beam Interlock System through 2 redundant connections. Likewise, the raster system shall connect to the ESS run permit system, which assures that the equipment is configured according to the accelerator operational mode (e.g. beam energy).

2.5 Mechanical and survey

The mechanical system shall be built according to modern standards within the accelerator business. The systems shall apply to all normal European standards.

An adequate support stand shall be supplied for the system of raster magnets. The 8 raster magnets of the production series shall be placed with mirror symmetry, hhvv-vvhh, where h and v indicate horizontal and vertical raster magnet, i.e. producing vertical and horizontal AC field components, respectively. In the middle of the system, indicated by -, a beam instrumentation module is to be located (not part of delivery), cf. Figure 1, hence two separate and identical (apart from mirror symmetry) support stands could be strongly favored. Each magnet stand shall be no wider than 600 mm. The vacuum system of each 4-magnet setup shall be no longer than 1800 mm (flange end to end), and the magnet stand shall stay within this envelope.

The support stands shall be built from materials that do not influence the quality of the magnetic fields produced by the magnets.

The magnets shall be fixed on their support stands. Considering the number of individual magnets, a baseplate or girder shall commonly align the four magnets on a support stand. The supports of the ceramic chambers shall enable the possibility to align the chambers relative to the girder to ±0.5 mm or better.

The support stand girders shall be mounted on 3 or 4 feet allowing easy movement with mechanical movers, e.g. turnbuckle systems, relative to the support stand base. The displacement range shall be +/- 50 mm in all three dimensions: horizontal, vertical and longitudinal.

The beam height, i.e. from magnet centres to the floor should be 1500 mm.

For the fast magnet elements, alignment monuments shall be available allowing external positioning of the elements to an accuracy of 0.5 mm transversely, 0.3

mm longitudinally and with angular tolerances of +/- 1.0 mrad (pitch/yaw/roll) with a laser tracker and precision inclinometer.

The reference positions for the above fiducials shall be determined by the manufacturer and approved by the Contracting Authority.

Lifting eyes shall be available. All equipment shall in addition be designed to use pallet trucks or equivalent mechanical handling devices for initial positioning.

2.6 Vacuum

The vacuum system shall be built according to normal UHV practices. In particular this means that only Conflat joint technology shall be used. Additionally, to reduce the time to replace components of the system that is to be located in a region where elevated radiation doses are expected, Quick Conflat flanges shall be used in the system. All bellows shall be hydroformed.

The ceramic cylindrical vacuum chambers shall be fitted with metallic end-flanges. Apart from these, no additional ports are required for pumping and gauges. Pumps and gauges are in general not part of the purchase. The need for a thin metallization layer on the inside of the ceramic chambers to conduct proton beam image currents and avoid charge build-up shall be investigated. Based on the findings, the Contracting Authority shall decide whether the supplier needs to metallize the chambers.

The vacuum systems are not foreseen to be baked due to the modest operational vacuum pressures, yet it shall still only apply UHV-compliant vacuum components.

2.7 Water cooling

If possible, it is preferable to avoid water cooling systems in both the magnets and their concomitant supplies. The water cooling systems, if needed, shall be built according to modern standards within the accelerator business. The systems shall apply to all normal European standards.

All coils shall be made from solid OF copper, possibly with a central cooling hole. The coils shall be designed for a maximum temperature rise of 10° for a differential pressure of 3 Bar. A maximum temperature of the coil will be less than 35 C for an inlet temperature of 20 C.

The magnets, if water cooling is needed, shall include a water manifold system mounted on each magnet with only one water inlet/outlet for each magnet.

An over-temperature relay sensor shall be fitted on the outlet of each coil, set to open an electrical circuit at 60 C.

2.8 Radiation resistance of system materials

The system will eventually be installed in a region where elevated radiation levels are to be expected, originating in particular from uncontrolled losses of the high-intensity proton beam. The dose levels at ~10 cm from the beam are expected to be of the order of 10 MGy during the facility's lifetime, 45 years. At locations either further away or in shade of dense materials, significantly lower doses are expected, e.g. lower by an order of magnitude. System components should preferably be able to withstand the radiation for at least 10 years. The Supplier shall present a consideration of radiation resistance and expected lifetime of the materials intended to be used for the system, in particular the parts that will be close to the primary proton beam.
It should be noted that the power supplies are to be located in a remote room offering radiation levels suitable for electronics and are thus irrelevant in this respect.

3. Testing

Before advancing from phase 1 to phase 2 (cf. schedule listed in ITT), the contractor shall specify the planned factory acceptance test procedures to be made at the factory/sub-contractor before delivery of the pre-series and the full production series, Factory Acceptance Test I+II, respectively. The Contracting Authority shall approve the planned tests.

Testing, as specified below, shall be performed at the factory after production and assembly. The results of the tests will be kept and delivered to the customer together with the components.

Site acceptance tests of the pre-series and production series, Site Acceptance Test I+II, respectively, will mostly include visual inspection for potential mechanical damage suffered in transit. Following the Site Acceptance Test I, the Pre-series Performance Test will be conducted by the Costumer. This involves a long-term stability test during which the system will be set to follow nominal operational specifications for a period of several months, cf. schedule in Instructions To Tenderers. If found feasible, the pre-series may also during this be tested with a suitable accelerator beam available at the customer. The beam test should bear no expense for the Supplier.

Standard accelerometers and tilt monitors on the equipment are required to certify proper transport.

3.1 Mechanical

Critical dimensions like magnet gap and its parallelism shall be measured. Important measures are transverse and vertical location, tilt and roll.

All mechanical interfaces to vacuum and support structures shall be checked.

The adjustment range on the magnet support shall be demonstrated.

3.2 Electrical

The parameters of the power cables between each supply and magnet shall be tested and their electrical parameters shall be confirmed. All raster system tests shall be performed with the full nominal length power cable in use.

3.3 Magnetic

All magnets shall have their transfer function documented within their operating range. Using suitable integrating coils, measurements of the primary fields, transverse homogeneity in the magnet good field region, and the field leakage shall be performed while paying attention to possible bandwidth limitations of the measurement.

3.4 Vacuum

The system shall be vacuum He leak tested to 1E-10 mbar.L/s using standard UHV practices. Only oil-free equipment shall be allowed for the test procedure. A thermal outgassing rate of the ceramics of 5E-9 mbar.L/s.cm^2 or better shall be verified.

3.5 Water cooling

Water cooling properties should, if used, be recorded.

3.6 Suggested spare parts and consumables

A list of the components with expected finite lifetimes (< 10 years) shall be supplied to the Contracting Authority at delivery together with their expected lifetime and replacement or refurbishment price.

4. Parameter lists regarding the raster magnet system for ESS

Table 1 **ESS Beam Parameters**

Parameter	Unit	Nominal	Min	Max
Beam rigidity	T.m	9.29	2.15	9.29
Beam kinetic energy	GeV	2.0	0.20	2.0
Beam pulse rep. rate	Hz	14	<1	14
Beam duty cycle	%	4.0		4.0
Beam pulse duration	ms	2.86	0.1	2.86

Table 2 **ESS Raster Magnet Minimum Requirements**

Parameter	Unit	
Type of magnet	N/A	Out of vacuum
Number of magnets	N/A	2 + 8 (pre-series + production series). Production series include 4 x H and 4 x V magnets
Max. mechanical length	mm	400
Vacuum chamber type	N/A	Cylindrical. Ceramic, possibly with a metallization layer
Minimum vacuum chamber inner diameter	mm	80
Nominal operational pressure	mbar	1E-7 or lower
Cable length between magnet and power supply	m	30
Yoke assembly	N/A	Split yoke
Maximum raster system repetition rate	Hz	14
Raster direction or waveform polarity	N/A	Alternates from pulse to pulse
Nominal raster system duty cycle	%	5
Maximum raster pulse duration	ms	3.57
Field waveform shape	N/A	Bipolar triangle with zero offset. Assumed identical in shape to the magnet current waveform
Nom. waveform fundamental frequency	kHz	40 in H, 29 in V
Min. applicable	kHz	10

waveform frequency		
Max. applicable waveform frequency	kHz	40
Bandwidth of the entire magnet system, fBW (-3 dB bandwidth)	kHz	200 (fifth harmonic)
Synchronization of waveforms	N/A	The synchronization of the phase of the triangular waveforms with respect to the initiating pre-trigger shall be accurate to less than or equal to ±200 ns
Rastering amplitude accuracy	%	1
Peak precision (during pulse)	%	1
Peak precision (pulse-to-pulse)	%	1
Raster deflection offset (pulse-averaged deflection)	%	1 or lower
Max. bending strength, BL	mT.m	±5.0
Nom. peak bending strength, BL	mT.m	±2.6
Magnetic length*	mm	300
Nom. deflection angle per magnet	mrad	0.280
Nominal dipole field amplitude*	mT	8.7
Operating range	%	20-150
Good field region	mm^2	30×30
Good field definition		*Δ(∫Bdl)/∫Bdl*
Field homogeneity in good field region	%	10 or lower
Mechanical edge angle incident/exit	°	0/0 (beam deflection introduced by raster magnets are disregarded here)
Max. leak field at end flange of 4-magnet arrangement	% of peak field	5 or less to avoid eddy current heating in metallic parts

Parameters marked with * are merely suggestive values, and do not represent requirements.

Table 3 **ESS Raster Magnet Power Supply Specifications**

Parameter	**Unit**	
Type of supply	N/A	Could be a capacitor charging supply combined with a fast H-bridge
Local controls and regulation	N/A	Each supply shall provide local control electronics (incl. local control system) and suitable regulation loops to meet the specifications.
Number of supplies	N/A	One per magnet: 2 + 8 (pre-series + production series). If found acceptable, the 2 pre-series supplies can possibly be a part of the supplies of the production series.
Supply form factor	N/A	The raster system supplies shall fit into 2 full-height 19" racks
Raster timing and beam mode	N/A	Each RSM power supply shall receive timing and beam mode information (e.g. beam energy) from a timing receiver (existing hardware provided by the ESS)
Beam interlock	N/A	The RSM Local Protection System unit shall deliver an OK/NOK signal for the Beam Interlock System through 2 redundant connections
Beam run permit	N/A	The raster system shall connect to the ESS Run Permit System, which assures that equipment is configured according to the operational mode