Specification

EUROPEAN SPALLATION SOURCE ERIC

Design Specifications for a Wide aperture Vertical Asymmetric Magnet for neutron scattering

02-2020

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Revision Details		*Print name, date and initial each box*			
Rev. Letter	**Description of Revision**	**Prepared**	**Reviewed**	**Approved** *(Procurement)*	**Agreed** *(Customer)*
A	Initial issue	A. Holmes			
B	**Revised after CTR**	Name / /	Name / /	Name / /	Name / /
C		Name / /	Name / /	Name / /	Name / /
D		Name / /	Name / /	Name / /	Name / /
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Notes:
1. Each revision must be approved by the Procurement Officer.
2. Each revision must be agreed by the Customer.

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1. Title

Specifications for a vertical asymmetric superconducting magnet with a variable temperature insert to be procured by the Laboratoire Louis Brillouin (LLB) as part of an in-kind procurement for the European Spallation Source ERIC (ESS).

2. List of Contents

The first part of the document (sections 3 and 4) sets the background and describes the generality of the magnet to be procured.

In the second part of the document are tabled the detailed specifications. The general specifications for a split-coil, asymmetric, vertical-field magnet, with closed-cycle cooling are set in section 6. The same section details the requirements for the neutron access and general dimensional limits. Software requirements are specified in section 6.4, safety requirements section 6.6, and acceptance test and required documentation in section 6.7.

The dimensions are provided in the specification tables. Assembly requirements and a general overview of the dimensions are sketched in the attached six PDF files, which are an integral part of this document. The list of attached documents is in section 6.12.

The project delivery schedule is provided in section 6.10.

3. Introduction

European Spallation Source (ESS) is a European Research Infrastructure Consortium (ERIC), a multi-disciplinary research facility based on the world's most powerful neutron source. Our vision is to build and operate the world's most powerful neutron source, enabling scientific breakthroughs in research related to materials, energy, health and the environment, and addressing some of the most important societal challenges of our time. The ESS is under construction on the outskirts of Lund, a city in southern Sweden. The facility's unique capabilities will both greatly exceed and complement those of today's leading neutron sources, enabling new opportunities for researchers across the spectrum of scientific discovery, including materials and life sciences, energy, environmental technology, cultural heritage and fundamental physics.

The facility has 15 neutron instruments planned during the construction phase, along with a suite of sample environment equipment which will be used to manipulate a sample's physical conditions in the neutron beam. The sample environment equipment may be installed on different instruments, depending on the experimental requirements, and efforts are made to achieve design and procure equipment that could cover as many instruments and scientific requirements as possible, to maximise the efficiency of the facility.

ESS is a large scale European collaboration with many components being provided in-kind by member countries and their respective institues. This magnet will be procured by the Laboratoire Louis Brillouin (LLB) as part of their in-kind contribution to ESS.

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4. Scope

LLB/ESS is seeking offers for the design and construction of a Vertical Asymmetric Magnetic Field Superconducting Magnet with a minimum central magnetic field of 8 Tesla and a variable temperature insert (VTI) that may allow the insertion and cooling of a future dilution insert (still to be built and not included in this procurement). The magnet will be used to perform scientific experiments with high magnetic fields and low temperatures (minimum temperature achievable ≤1.6 K, or ≤ 50 mK in combination with ULT inserts) on various neutron-scattering instruments, with a particular focus on the Magnetic single crystal diffraction instrument MAGIC. The other target instruments are the powder diffractometers DREAM and HEIMDAL. This document details the technical specifications that provide the information to assist in the design, fabrication and delivery of the magnet. Requirements referred to as 'must' or 'essential' are qualifying requirements for a tender response to be considered. Requirements referred to as 'desirable' or 'should' will be favourably viewed when considering responses. 'Highly desirable' indicates a strong weight will be given to this criteria.

ESS has a helium recovery and reliquefaction system at its disposal. Therefore both wet and recondensing systems should be considered and quoted. If only one type is proposed, a wet system is preferred.

The asymmetric magnet will be used to perform scattering experiments with polarised neutrons at different instrument locations. It is not intended for use with polarisation analysis, and instruments are subject to strict guidelines on magnetic materials in the sample area. However stray field must be limited to 30 G at 2.5 m from the sample position in the horizontal plane and should be minimised where this does not otherwise significantly affect the magnet performance in terms of central field, opening angle, or homogeneity.

Neutron experiments involve placing a sample (generally of a volume around 1 cm^3) inside the magnetic field produced by the magnet at a certain temperature while exposing it to a neutron beam. The temperature and field must be stable over a long period of time (>24 h) without drifts. The asymmetric magnet will be placed on different instruments at ESS; therefore it must be portable when cold, at zero field and not energised.

Kinematic mounts will ensure repeatable positioning of the magnet on every instrument, implying the sample must be centred within the magnet with similar accuracy.

The vendor will provide the detailed technical design of the magnet, a complete list of ancillary equipment necessary to operate it, a list of the materials certificates, technical and operating manuals, instrument controls, and appropriate software for the remote operations of the equipment stand-alone and via the neutron instruments' control software. The vendor will also provide a detailed study of the fringe magnetic field including the fringe-field gradient as specified in the specifications tables of section 6. Coil-defining files will be provided so that gradients and forces can be subsequently calculated. The magnet must be designed to withstand forces up to 1000 N due to magnetic material in the vicinity. The exact limits must be specified by the vendor.

5. List of Applicable Documents

All supplied equipment be CE marked and must comply with the European Standards

PED 20/68/EU with harmonised standards

EN 13445 - Pressure vessel manufacture

EN 13480 Piping

EN 13458-2 Cryo

To vary any of the manufacturing standards consent must be obtained from the ESS Project Manager prior to implementation.

As vacuum vessels are considered pressure vessels, the manufacturer will provide all necessary information including the detailed design of the pressure and vacuum vessels.

For certification purposes the following information must be detailed after manufacturing:

1. Manufacturer's data report with vessels volumes noted
2. Manufacturing records
3. Materials certificates
4. Weld procedures
5. Weld-traceability records
6. Dimensional inspections
7. Non-destructive examination
8. Pressure-vessel testing (vacuum)
9. Relief-valves test certificates/report
10. Leak test

The free spinning lifting collared eyebolts must be CE marked and the supplier will provide a load test certificate.

6. Detailed Requirements

The asymmetric vertical-field split-coil magnet will be optimised for single crystal diffraction with the ability to be used on powder diffraction and spectroscopy instruments as well. The preferred design will require one side, the scattering side, having a 120° horizontal opening, with a +15° -35° vertical opening. Due to the different scattering geometries of the targeted instruments the remaining openings will allow the access of the incoming beam through apertures of minimum 20 mm diameter (see details in the drawings provided).

The magnet tail will be provided with Aluminium (Al) windows of reduced thickness in a cylindrical geometry. The design should aim at reducing or eliminating the amount of Al in the incoming neutron beam and scattering path. The incoming and outgoing main beam path equipped with the absolute minimum of Al needed for thermal, vacuum and structural requirements. In order to further reduce background neutron scattering, faces exposed to secondary scattering from the sample or otherwise within the magnet must be coated with a neutron absorbing layer, either by the vendor (preferred) or in close coordination with ESS/LLB. For more details see magnet specification tables and attached drawings. The following items will be part of the magnet deliverables, in addition to the cryomagnet itself:

a) Variable Temperature Insert (VTI) equipped with motorised rotation (360°) and z (+/-20mm) stage with a minimum resolution of 0.01º and 0.1 mm vertically. The motion components must follow the ESS MCAG hardware standards unless alternatives are agreed. This includes stepper motor, absolute SSI encoder and limit switches.
b) Magnet power supply
c) Current and signal cables (all cables 10 m long, flexible)
d) Two sample-mounting sticks, adjustable in height, with 2 Cernox 1050 CU type calibrated sensors (or equivalent calibrated sensors) appropriate for the temperature

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range 1.4 K to 325 K with maximum error <0.1 K. One sensor mounted at the end of the stick and one floating, with the ability to reach 100 mm below the end of the sample stick. The sticks should have 3 ports – one for the stick sensors & heaters, one unwired multi-pin connector with 12 contacts and one KF16 port. ESS must be consulted before choosing connector types.

e) Siphons and tubing needed for liquid nitrogen pre-cooling and helium filling as appropriate.
f) Level probes and meters with low and high level indicator for automatic filling.
g) All pumps provided for the evacuation and ^{4}He recirculation must be dry pumps, ESS must be consulted before final choice of pump.
h) Electronic equipment for temperature regulation and magnet control, including persistent switch heater, housed in a wheeled 19" rack, equipped with CE certified swivelled lifting eyes.
i) Software for the remote operation of the magnet and temperature regulation running on a local PC included with the system.

The VTI will allow the sample to be maintained at any temperature between 1.6 K and 325 K, with a temperature stability of better than 1% over 1 hour, with the sample in static exchange gas. The VTI will allow samples to be mounted with a sample-positioning stick from the top of the magnet; it should be possible to change sample at any temperature. The system will allow closed loop control at both the VTI heat exchanger and sample stick. A motorised rotation a vertical Z motion stage with stepper motor and an absolute encoder will allow the sample rotation and vertical translation in the neutron beam. The motor and encoder will be compatible with the ESS MCAG Beckhoff motion controller. A suitable controller can be provided on request for testing and development purposes. The sample will be positioned at the centre of a Ø 10 mm sphere of ±1 % or better magnetic homogeneity. The axis of the field and the axis of sample rotation must be concentric (better than 0.2 mm) and coaxial (better than 0.1°). The resolution for the rotation stage must be better than 0.01°.

The magnet must include a persistent switch. It must be safely operated even in the event of a quench, and the system must include passive and active quench detection and protection.

The design of the system must be checked by LLB/ESS for its compliance with these Specifications before commencing production. This is a Hold Point for the project and it will be necessary to obtain written approval by the Project Manager or delegate before proceeding to the next stage (manufacturing). The LLB in-kind project manager or delegate is the only person that may give the necessary approval to proceed. Any rectification work, required as a result of proceeding past this Hold Point without approval, will be the responsibility of the vendor.

6.1 Technical Characteristics (Magnet)

The key specifications for the vertical asymmetric magnet are listed in the following tables:

Magnet bore	Scattering angle	Neutron access	Vertical opening	Central field	Fringe field
50 mm minimum accessible to user	120°on left side (see drawing)	20 mm open path	+15° to -35°	≥8T	Uncompensated, zero field position outside neutron trajectory. Maximum 30 Gauss at 2.5 m

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The vendors, in their submission package, must provide simulated field maps proving the fringe-field requirement is satisfied. More details are provided in section 6.2 d).

The magnet asymmetry requirement can be satisfied when the zero-field-point usually located near the surface of the magnet is sufficiently away from the accessible neutron trajectories. The vendors, in their submission package, should indicate how they intend to achieve the strict asymmetry requirements and must provide graphs from the simulations that prove the asymmetry requirement is satisfied. More information about the asymmetry requirements are provided in section 6.2 a)

No.	Item	Description	Importance
1.	Maximum field	>8 T (asymmetric) under normal operation conditions	Essential
2.	Geometry	Split-coil pair, vertical magnetic field optimised for diffraction with polarised neutrons	Essential
3.	Asymmetry	Asymmetric outer field with zero-field node position outside the neutron flight path (see section 6.2 a)	Essential
4.	Neutron access (vertical)	Split with vertically tapered aperture ≥ +10°/-30° ≥ +12°/-33° ≥ +15°/-35° (See Figure 1 and section 6.2 b) clarification) scattered beam access to cylindrical volume 10mm diameter, 10mm height.	Essential Preferred Highly Desirable
5.	Neutron access (horizontal)	Split coils; the split supports must not restrict the horizontal scattering angle to less than 120° on the scattering side (see possible concepts for alternative arrangements in the Figure 2 and section 6.2). The design must minimise the Al thickness and surfaces on the scattering side.	Essential
6.	Backscattering	12° conical access around incoming beam.	Highly Desirable
7.	Accessible sample space diameter	50 mm ≥ 60 mm	Essential Desirable
8.	Internal Shielding	Magnet split inner surfaces covered with neutron absorbing coating agreed with ESS. Mounting points for externally provided shielding materia, 2-3 mm thickness.	Highly Desirable Essential if shielding not provided by vendor.
9.	Homogeneity	Field homogeneity ±1 % or better at the sample position over a 10 mm diameter spherical volume.	Essential
10.	Magnet	Sweeping rate 0.5 T/min after first field. Field sweeping rate should be optimised to obtain the maximum sweeping speed without incurring a magnet quench.	Desirable
11.	Magnet	Software controlled remotely operated switch between operation in persistent and driven modes. The supplier will indicate the electric power dissipation and switch resistance with the switch on.	Essential

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12.	Field stability	Rate of field decrease: less than 1% a week in the persistent mode. Field stability ≤ 5 Gauss in driven mode.	Minimum
13.	Protection circuit	Protection of the coils in the event of a quench or power failure. The total energy dissipated in the quench event should be indicated by the supplier.	Essential
14.	Recovery	Recovery time after a quench must be no longer than 12 hours.	Desirable
15.	Cryostat	Wet (He4)	Desirable
16.	Cryostat	System cooling from room temperature in less than 48 hours	Essential
17.	Cryostat	Hold time (wet cryostat) >= 4 days (idle) >= 2 days (base temperature, zero field) Recondensing option: zero boiloff when VTI stable at base temperature and magnet in persistent mode.	Essential
18.	Cryostat	Helium fill port diameter: 12mm	Essential
19.	Cryostat	Helium recovery connection port: KF40 flange	Essential
20.	Diagnostic thermometers	Generically calibrated thermometers located at: • Coil base (on 4K shield) • Helium Reservoir (0% level) • Superconducting switch • Thermal radiation shield (i.e. LN2/40K shield) at furthest point from cooling source, with connection to allow removal of shield for maintenance if required.	Essential
21.	Field Diagnostic	Measurement (e.g. hall probe) of field strength at fixed position on 4K shield.	Essential
22.	OVC	Bottom tails of the thermal shield and OVC made of Al alloy validated by ESS to ensure no unacceptable activation by neutron exposure. Anywhere on main beam absolute minimum of material, total < 8 mm. OVC neutron scattering section thinned to 1 to 2 mm thickness.	Essential
23.	OVC	The bottom tails must be removable and equipped with an interface matching the ESS kinematic mount level 1 (ESS-1797666.2).	Essential
24.	OVC	OVC evacuation port KF 25 flange.	Essential
25.	OVC	OVC ^{4}He leak rate during cool-down RT => 4 K below 10^{-9} mbar l/s	Essential
26.	Mass	Total weight limit (including VTI and cryogens): ≤ 950 kg	Essential
27.	Dimensions	Outer dimension limit (see drawings): Main body maximum diameter ≤ 780mm Tail diameter ≤ 780 mm Total height h ≤ 1800 mm Height above sample position including dilution insert ≤ 2100mm Preferred tail diameter = 580 mm	Essential Essential Essential Essential Desirable
28.	Dimension	Distance between the neutron beam (magnet centre) and kinematic mount reference plane = 500 mm	Essential

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29.	Handling	Certified metric swivel eye-bolts for safe crane handling with 3 equispaced lifting points	Essential
30.	Software	Magnet power supply and functions as well as temperature control must be provided with remote control software. The software must be able to accept external commands and report status as a string of ASCII characters with a TCP/IP protocol through an Ethernet port (see §6.4.1).	Essential
31.	Software	Communications using the SECOP protocol: https://github.com/SampleEnvironment/SECoP	Desirable
32.	Motion control	Sample stick/insert rotation stage Range 360° Resolution 0.01° Rotation rate 2°/s Useable at max field	 Essential Desirable
33.	Motion control	Z (vertical) adjustment of sample stick. Range +/- 20mm Resolution 0.1mm Speed 1 mm/s Useable at max field	 Essential Desirable

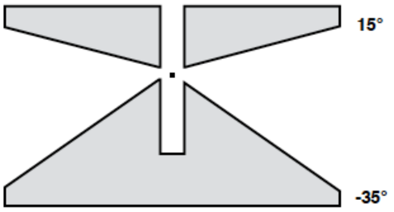

Figure 1 Vertical assymmetric opening above and below beam position.

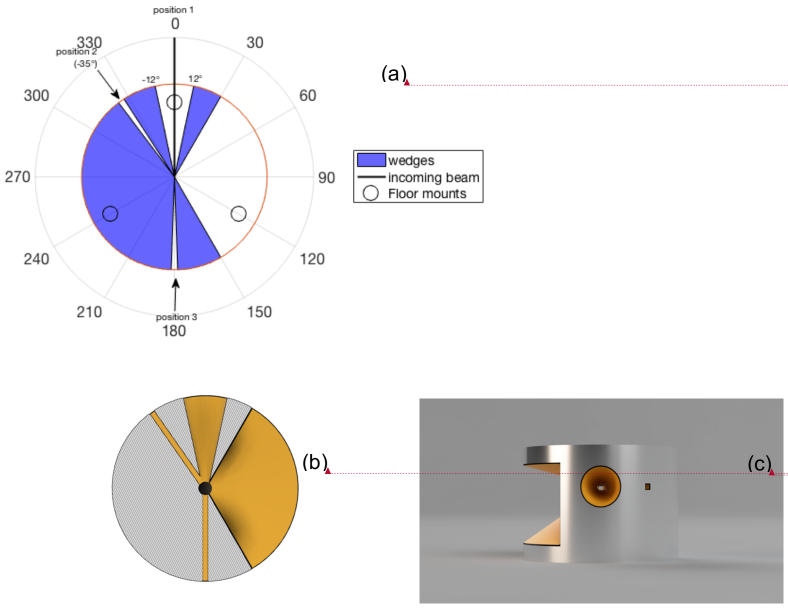

Figure 2 (a), (b) Schematic top views of horizontal scattering plane, showing potential free paths for incoming outgoing and scattered neutrons. Three mounting positions are envisaged, with the beam entering at the positions shown as 0°, -35° and 180°. (c) View from incoming beam direction (position 1), showing +/- 12° conical aperture for backscattering

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6.2 Functional Characteristics

a) In the following specification details, cylindrical coordinates r = (R,z,φ) are used. R = radius from magnet central axis, z = vertical distance from the equatorial plane, R = 0 & z = 0 identify the magnet centre and centre of sample volume, B = magnetic field magnitude with B(0) = central field, and α = angle of field with magnet's vertical axis.

The required asymmetry (ratio of angular change to local field) must satisfy the following equation:

$$\frac{1}{B(M)}\frac{d\alpha}{dR} \leq 1700\, rad/T \cdot m$$

at R ≤1 m at any point in any neutron trajectories for B(0) ≥0.2T. This will guarantee a depolarisation of less than 1% for neutrons of 0.6 Å for a central field B(0) ≥0.2T.

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gives the maximum angular change of the field direction. If the magnetic field is axial symmetric:

$$|\nabla\alpha(R,z)| = \sqrt{\left(\frac{\partial\alpha}{\partial R}\right)^2 + \left(\frac{\partial\alpha}{\partial z}\right)^2}$$

This requirement can be satisfied when the zero-field region is located sufficiently far from any neutron trajectories.

Simulated field-gradient map

$$|\nabla\alpha(r)| / B(r)$$

at B(0) = 0.2T, 1T and maximum achievable central field $|B(0)|_{maximum}$, for the cylindrical volume contain neutron trajectories out to R=2m at no more than 10mm step size in R & z and 10° angular steps, must be provided to prove the above criterion is satisfied. If the magnetic field map is axially-symmetric, an area map from the magnet centre to R=2m that contains the neutron trajectories is sufficient. The calculations can be provided as a plot or as tables in electronic format.

b) The vertical access angle of the neutrons scattered at the edge of a 10 mm height sample, with the desired accessible bore size of 50mm, must be ensured by the conical taper with the preferred vertical aperture of +15°/-35° to allow a high illumination of the MAGiC detector. Smaller vertical apertures +12°/-33° and +10°/-30° can be considered as an alternative design and the gain in terms of maximum central field and reduced fringe field described in the context of the magnet overall dimensions, performance and cost in the tender submission. This should include any neutron absorbing material.

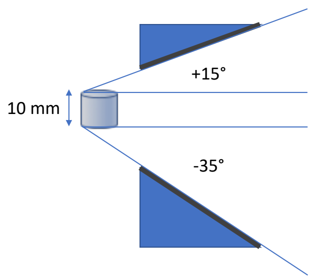

Figure 3 – Neutron access

c) The minimised Al thickness refers to the possible path that the neutrons scattered from the samples may travel before leaving the magnet. The idea is to provide the largest possible horizontal scattering angle (θ ≥ 120° on the scattering side) minimizing the amount of Al in the flight path. The total Al thickness in the scattering-side beam should be ≤ 8 mm. Holes through the Al coil separators should be provided to minimise attenuation of neutrons in the incident beam (see drawings). The supplier should provide the calculated Al thickness in the neutron paths. Any "dark angle" should be positioned preferentially to the right-hand side of the neutron path as seen by the incoming neutrons. In the attached drawings alternative designs and arrangements for the split support are illustrated. The ESS reserves the right to choose the design which better fulfils our research requirements.

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d) The vendor must provide in the proposal two calculations: the first one showing the fringe magnetic field B(r) and a second one showing the maximum field-direction angular change

$$|\nabla \alpha(r)|$$

in a cylindrical volume up to R ≤10 m and -3 m ≤z ≤ +3 m at the maximum achievable central field $|B(0)|_{maximum}$, in step sizes no more than 20 mm for R & z and 10° angular steps. If the magnetic field is axially-symmetric, area maps of B(R,z) and α(R,z) are sufficient. The fringe field must be overall minimised especially in the equatorial plane. The fringe-field calculations can be provided as a plot or as tables in electronic format. The fringe-field should rapidly decrease with no peaks or fluctuations.

6.3 Performance Characteristics (VTI)

The magnet will be provided with a variable temperature insert (VTI) to allow a fast access to the sample from the top of the magnet. The VTI must be able to accommodate variable-height sample-centring sticks in such a way that the samples are held at the centre of the split i.e. at the beam-centre position. The VTI dimension must be such to accommodate the magnet, with enough cooling power to be able to cool and run at base temperature a possible future dilution fridge or ^{3}He sorption insert (not included in this tender) and to allow a good temperature regulation as referenced in the following Table. In order to minimise remnant flux all components must be non-magnetic.

No.	Item	Description	Importance
1.	Temperature Range	Temperature range for VTI and sample stick (exchange-gas pressure ~ 500 mbar at 300 K) guaranteed to be operated in the range T = ≤1.6 K to T = 325 K. Measured at sample position on sample stick.	Essential
2.	Performances	Temperature difference between VTI and sample stick guaranteed ΔT < 0.1 K at 1.5 K; ΔT < 0.2 K at 5 K and above	Desirable
3.	Cooling	LHe cooling controlled by automated needle valve and subsequent capillary to heat-exchange gas. Cooling power > 0.5 W at 10 K	Essential
4.	Cooling	Sample cooling from room temperature to base temperature t ≤ 1 hours with VTI starting at 100 K.	Highly Desirable
5.	Heating	Sample heating from base temperature to 300 K t ≤ 0.5 hours.	Essential
6.	Heating	Capillary heater and thermometer NV heater and NV shaft heater	Essential
7.	Automation	Manual and automated needle valve with stepper motor selected from ESS approved models. Pumping pressure with pressure range from P = 10^{-2} mbar to P = 1 bar. The pressure controls the NV opening alternatively to the temperature.	Essential

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8	Thermometers	Thermometers all CERNOX 1050 CU-type (non-magnetic package) or equivalent.	Essential
9	Sample Thermometer	CERNOX 1050 (or equivalent) sample thermometer calibrated for temperatures from T = 1.4 K to T = 325 K	Essential
10	Sample heater	Thin-film resistor for sample heating, non magnetic.	Essential
11	Heat exchanger	Heat exchanger with CERNOX 1050 (or equivalent) thermometer calibrated with temperature range from T = 1.4 to T = 325 K	Essential
12	Heat exchanger	Heat-exchanger with non-magnetic heater.	Essential
13	Temperature controller	Temperature controller compatible with CERNOX 1050 thermometers measuring to 1.4 K with 1mK resolution. 2 independent PID control loops. 4-8 thermometer channels.	Essential
14	Control loop	VTI => Ch. 1 with primary regulation circuit, Sample => Ch. 2 with 2nd regulation circuit.	Essential
15	Pumping tube	Co-axial pumping tube around thin-walled sample tube with NW40 port	Essential
16	Pumping system	VTI served by dry pump (He tight) for gas He at 1.6 K pumping speed => from 20 to 35 m^3/h	Minimum
17	Materials	VTI bottom tail (below Cu-heat-exchanger) made from Al alloy with In seal and neutron window of minimised thickness	Essential
18	Dimensions	Sample tube with minimum inner clearance diameter D = 50 mm and NW50 flange.	Essential
19	Dimensions	Minimum free space below sample position 70 mm.	Essential
20	Valves	^{4}He exchange-gas flushing valves and ^{4}He flushing with electronic pressure gauge (range: 10^{-4} mbar to 1500 mbar).	Essential
21	Wiring	2 interchangeable non-magnetic sample sticks with baffles and Cu puck accommodating the heater and thermometer. Second thermometer able to reach 100 mm below the sample centre	Essential
22	Wiring	All thermometer and heater wires twisted pair, non-inductively installed. Thermometers connected by 4-wire method.	Essential

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6.4 Interfaces

6.4.1 Communication:

The magnet and VTI will be fully controlled by software running on a control PC supplied with the system, enabling stand-alone operation with user-friendly interface, diagnostic logging etc. The system software will be subordinated to the ESS instruments' control software therefore the vendor must provide all information necessary to enable its integration. The communication between ESS neutron beam instruments control software (ICS) and the magnet-system software will be through a TCP/IP socket. The communication between the magnet control

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software and ICS will be through simple ASCII string of commands. The vendor must provide a fully documented remote control manual.

Requirements for devices that shall be connected to the ESS (EPICS-based) Integrated Control System:

If the device is not based on the standard ESS Hardware platforms [ESS-0067637, ESS-0037909], the following shall apply:

The device shall be able communicate over Ethernet network.
Alternatively, if Ethernet interface is not possible, a serial port (RS-232, RS-485) can also be accepted.
This should however be an exception and has to be approved case by case.

For Ethernet-based devices, the equipment provider shall provide means for:
-internal software upgrades, when applicable (e.g., operating system updates)
-applying security patches, when applicable
-remote support as needed by the equipment responsible.

Long-term maintainability of the control system interface must to be possible by ESS. Maintenance includes adaptation to the ESS environment (EPICS, etc.), possible extensions to the EPICS interface and possible new features.

Long-term maintainability implies that if the device has high-level internal control functions (built-in device server, e.g, EPICS (*)), it shall be possible to access all the related configuration and also to upgrade the internal system as needed. This means either making available source code for the internal control software and documentation that is sufficient to enable modifying the system, or having a possibility for a long-term maintenance contract by the manufacturer.
When source code is supplied, it should be one of the languages that ICS supports (C, C++, Java, Python).

Defined periods of guaranteed availability of the same system, or a fully compatible one should be stated.

Specifically for devices that communicate over Ethernet:

The software must be able to accept external commands and report status as a string of ASCII characters with a TCP/IP protocol through an Ethernet port.

A complete list of standard commands shall be provided.

Use of standard protocols is preferred but not mandatory.
Standard protocols that are accepted include SCPI (**IEC 60488-2-2004)** and Modbus/TCP. SECoP (https://github.com/SampleEnvironment/SECoP) is the preferred standard.
Use of other protocol standards shall be discussed with and approved by ESS before procurement of devices.

All common options for configuring the Ethernet shall be available, like dynamic IP address assignment by DHCP.

The principal parameters to be available to the EPICS software for remote operations include the following:

a) Current (and magnetic field) set point: set and query
b) Current (and magnetic field) reading: query
c) Current ramp: set and query

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d) Output voltage: reading query
e) Stop current ramp: set
f) Persistent switch: on/off and query
g) Liquid-helium level: query
h) Liquid nitrogen level: query
i) Error-condition flag
j) Received command acknowledgment

The instrument should accept the magnetic field set point in current or in standard magnetic field units (Tesla). It should safely operate, rejecting out-of-range inputs and the current ramp function should operate in accordance with the magnets limitations to avoid quenches. Operation of the persistent switch must be handled by the magnet power supply *(i.e. the user must not be able to operate the persistent switch if the magnet is at field but the leads are at zero)*.

The VTI and sample sticks should have the following parameters fully available for remote operations:

i. Temperature set point: set and query
ii. Temperature reading: query
iii. Heater output level: set and query
iv. PID setting: set and query (for both channels on the Lakeshore 336)
v. Sensor type: set and query
vi. Sensor calibration curve: set and query
vii. ^{4}He recirculation pressure: set and query
viii. Needle valve position: set and query
ix. Error-condition flag
x. Received command acknowledgment

6.4.2 Motion Control

The rotation stage and z stage should be automated and remote controlled by the Beckhoff motion controller. Stepper motors and encoders should be only by types approved by the ESS MCAG. Stepper motors requiring a DC bus voltage of 48 V and current from 0.2 to 14 A are able to be controlled by the ESS motion control system. The preferred types of motor is the McLennan 23HT18C330 (see table below for more motor options). Preferred encoders are the Posital OCD-S101G-1416-S060-PRL as these encoders are the ESS motion systems standard. The details of encoders and step-motor mounting and cabling must be discussed with the Project Manager during the construction phase. If the application cannot fulfil the ESS MCAG recommended components please contact the Project Manager to discuss further options and solutions.

Commented [MOU2]: If the Z stage is included then a paragraph similar to this one should be added.

Supplier	Motor	Current bipolar (A)	Holding torque (Nm)	Flange size [mm]	Shaft ⌀	Motor length [mm]	NEMA	Price (EUR)	Standard level
Phytron	**ZSS.33.200.1.2**	1,2	0,075	32,0	4,00	68,5	-	198,00	
Phytron	**ZSS.43.200.2.5**	2,5	0,260	42,0	5,00	95,0	-	285,00	
Mclennan	**23HT18C330**	2,1	1,350	56,4	6,35	126,5	23	121,55	**L1**
Mclennan	**34HT18C340**	2,8	7,350	86,0	12,70	214,4	34	269,43	
Stögra	**SM 107.4.18 M6**	6,0	17,000	108,0	15,87	311,0	42	1028,65	

6.4.3 Mechanical interfaces

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Kinematic mounting

In order to minimise time needed to align samples in the neutron beam, ESS has established a standard kinematic mounting system and geometry for sample environment equipment. This is intended to ensure easy pre-alignment of samples to within a fraction of the sample size.

The dimensions and specification of the kinematic mounting system are described in ESS-1797666.2. The cryomagnet must be provided with an interface such that it fits with the ESS Level 1 floor mounted kinematic interface. This has a sample position 500mm above the reference plane indicated in the drawings. The field centre and sample position must be aligned to within +/- 0.5 mm of the nominal position at base temperature, taking account of thermal contractions. If the possibility of fine adjustment is needed to achieve this it must be included as part of the interface between the magnet body and kinematic mounting points. The sample sticks and rotation stage must also assure this aligment precision through the whole range of movement.

Sample mounting

The sample sticks must terminate with a [female threaded m6 hole, at least 6mm deep, coaxial with the stick, in an otherwise flat surface strictly perpendicular to the stick axis]. The end of the stick must be adjustable from 20 to 60mm above the beam position using the motorised z adjustment.

6.5 Packaging

Packaging suitable for secure transport to the ESS site in Lund should be used.

Shipping of the goods will be regulated by the rules described in Incoterms 2000. Shipment of the magnet and ancillary equipment is the responsibility of the vendor.

6.6 Security and Safety Aspects

All correspondence between the Project Manager and the vendor will be Commercial-in-Confidence. All correspondence will be through the Project Manager. All documentation will be Commercial-in-Confidence.

During installation, if required, contractor employees will be onsite at ESS. It is expected that ESS security documentation will be completed to allow the contractor employee to work at ESS.

Appropriate Induction and Safety training will be provided prior to contractor employees being engaged in the installation of the magnet and related equipment.

Based on ESS Risk Assessment a user Instruction document will be compiled for the magnet after installation and prior to ESS users gaining access to the equipment. This document will then become a controlled document within the ESS Document Management System.

The Vertical asymmetric magnet should operate safely and consistently. An automatic run-down procedure, remote controlled, should be provided. In case of a quench for whatever reason, the system must be designed to remain safe in all circumstances (run-down procedure, overpressure valves, etc...) The supplier should provide detailed instruction of the procedure to be carried out in case of such exceptional circumstances. The helium bath should be provided with a valve of adequate diameter and adjustable for emergency pressure relief in

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the event of an over pressure caused by a quench. In general all supplied equipment must comply with the European Standards. The manufacturer will provide all necessary information including the detailed design for certification purposes about the pressure and vacuum vessels with:

- concept drawings
- volume
- fluid type and state (liquid/gas)
- min/max operating pressure and temperature
- min/max design pressure and temperature

Furthermore for certification purposes the following information must be detailed:

- construction standard body
- materials certificates
- pressure vessel certificates
- relief valves certificates

The swivelled lifting collared eyebolts must be metric and must be CE marked, in particular the threaded socket must be designed to support the mass of: measured mass x 1.25 x 1.1. The manufacturer will supply a simple calculation verification.

The manufacturer will perform a load test at: measured mass x 1.1. The load test duration is 10 minutes. Thread must be inspected following the load test. The supplier will provide a load-test certificate.

From the electrical point of view, the magnet system should comply with the relevant European Standards, in particular any transformer must be an isolation transformer and not autotransformer, exposed low voltage (>50V ac) terminals are not allowed and earth bonding of all electrical metal enclosures must be provided.

6.7 Quality Requirements

The supplier should be accredited with a Quality Assurance (QA) system to a nationally recognised standard (eg ISO 9001). Subcontractors, involved in the supply of materials and components, should have a relevant quality system in place, which either complies with the appropriate European Standards or a recognised International Standard, or is otherwise acceptable to the Project Manager.

The supplier should arrange for all authorised corrective actions to be completed following receipt of non-conformance reports from the Project Manager. The Project Manager is the only person permitted to authorise disposition of non-conformance reports.

The test schedule for conformance will include testing of each of the Technical Characteristics and Performance Characteristics listed in section 6. The tests will be performed at the vendor facility in the presence of the Project Manager or nominated representative before shipping. During the testing phase, the main parameters agreed in this Specification and design phase in writing, will be verified: In particular, leak test, magnetic field achievable, fringe field at z=0, minimum temperature achievable, as well as field and temperature stability. In addition test will be conducted upon delivery and assembly at ESS premises to verify that no damages have incurred during transport and installation.

The following documentation should be provided:

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a. The supplier should provide the full documentation for certification purposes and manuals for the safe and reliable operations of the magnet and ancillaries.
b. The instruction manual will provide the standard operation procedure instructions and the actions to be taken in case of a system failure.
c. The standard operation should include the instructions for the system's first cool down and best practice for maintenance.
d. The documentation to be supplied will include the magnet-system drawings and the software documentation.
e. As-built drawings

All documentation should be provided in electronic and printed form.

6.8 Environmental Requirements

ESS is equipped with a helium recovery system, therefore a purely wet system is preferred. However if a closed cycle or recondensing system offers significant cost or technical advantages this can be considered as an option.

6.9 Design Contracts

The vendor is solely responsible for the design and manufacture of the magnet and ancillary equipment to the specification presented in this document. The Project Manager may be contacted for further information and clarification.

6.10 Timetable

It is essential that the design of the asymmetric magnet is completed no later than 6 months from the signing of the contract and that delivery will occur within 18 months of approval of the design documents.

6.11 List of Definitions and Abbreviations (optional)

ESS – European Spallation Source

LLB – Laboratoire Louis Brilloin

MCAG – Motion Control and Automation Group

CCC - closed cycle cryostat

DSV - diameter of spherical volume

LHe - liquid helium

NV - needle valve

OVC – Outer Vacuum Container

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QA - Quality Assurance

QC - Quality Control

SANS – Small Angle Neutron Scattering

TOF – Time of flight

VTI – Variable Temperature Insert

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