SR1 Sextupole Specification (SOA, SOB)

5.8.31.3 Rev. 0

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1. INTRODUCTION

1.1 Purpose

The Canadian Light Source requires thirty-six (36) sextupole magnets. These magnets are subdivided into two (2) different families: SOA, SOB. The SOA family consists of 24 multifunctional magnets with separate coil windings for sextupole, x-correction, y-correction, and skew-quadrupole functions. The SOB family consists of 12 dual function magnets with windings for sextupole, and skew-quadrupole functions.

1.2 Scope

This document specifies the requirements for the Canadian Light Source (CLS) storage ring (SR1) sextupole magnets and details the requirements for the design, and fabrication of the CLS storage ring sextupole magnets. This work includes, but is not limited to:

- All tooling including die sets
- Materials
- Equipment
- Commercial components
- Detailed drawings
- Prototype magnet
- Rotating Coil
- Fabrication
- Assembly
- Testing & Inspections
- QA/QC documentation

1.3 Background

The Canadian Light Source, CLS, is a national facility under construction on the University of Saskatchewan campus in Saskatoon, Saskatchewan. This facility will be a 3rd generation synchrotron light source, which will produce a high intensity source of infrared, visible, ultraviolet and x-ray radiation.

This facility requires 36 sextupoles (divided into two families: SOA, SOB) to be designed and manufactured for installation into the CLS storage ring. This storage ring will be capable of circulating electrons with energies of up to 2.9 GeV. These electrons will then be used as a source of synchrotron light.

References [2], [3], and [4] provide some background information to this specification.

2. REQUIREMENTS

2.1 Assembly

2.1.1 Sextupole magnet assembly should consist of the following major components:

- 3 Yokes
- 6 support plates
- 18 coils and support apparatus
- Electrical power bussing, thermal interlocks, and wiring
- Hydraulic assembly including input/output water manifold, hoses and fittings
- Mechanical fasteners and supports.

2.1.2 Electrical terminal blocks shall be manufactured from OFHC copper or equivalent.

2.1.3 Electrical connections between coils and terminal blocks for power leads shall be designed to be cooled using natural convection and operate at safe handling temperatures.

2.1.4 Buses shall be electrically isolated from the yoke. Proponent shall specify high voltage isolation test procedure for CLS review and acceptance.

2.1.5 Water supply and return fittings shall be clearly labelled to prevent misconnections.

2.1.6 Electrical isolation between water distribution manifold and coils shall be done with non-conductive hose.

2.1.7 The Proponent shall work with CLS to develop a method of final support for the magnet by a precision-machined girder prior to the final detailed design review by CLS.

2.1.8 Any additional holes or features required on the core assembly, other than those accepted by CLS on reviewed fabrication drawings, shall be reviewed and accepted by the CLS.

2.1.9 The Proponent shall develop a shuffling and flipping plan for laminations used in the assembly of the yokes for CLS review and acceptance. The laminations for the prototype need not be shuffled.

Rational: It is the intent of the CLS that all laminations be shuffled such that all magnet cores assembled are an average of the material used in the whole fabrication process.

2.1.10 All laminations shall be divided into magnet core groups prior to start of assembly of the first production magnet core to insure that all cores are fabricated from an average of all material used in the production of all magnets.

2.1.11 The magnetic axis of the assembly shall fall within a 0.100 mm diameter cylinder centered on the mechanical axis.

2.2 Fiducials

2.2.1 Fiducials shall be located at positions indicated on drawing SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).

2.2.2 Proponent shall provide six (6) fiducial marks on each yoke, accurately referenced to the mechanical center of the poles (represents beam center.)

2.2.3 Proponent shall provide data indicating the fiducial locations on each yoke when assembled into a complete magnet.

2.2.4 The fiducials shall be located using a right-hand Cartesian coordinate system (X,Y,Z), with the origin located at beam center in the plane of the pole face located on the right side when looking at the magnet from the services side of the magnet, as shown in drawing SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).

2.2.5 Fiducials locations (X,Y,Z) shall be determined within $\pm$ 25 μm.

2.3 Coils

2.3.1 The SOA family of magnets shall contain 18 coils arranged such that each pole contains 3 coils as illustrated in drawing SR1/ME/MAG/0037700 Rev A (SOA). This is a multifunctional magnet with coils to provide sextupole, x-correction, y-correction, and skew-quadrupole functions.

2.3.2 The SOB family of magnets shall contain 8 coils arranged such that each pole contains a sextupole coil, and the center vertical poles contain a skew-quadrupole winding as illustrated in drawing SR1/ME/MAG/0037900 Rev A (SOB).

2.3.3 Coils shall be vacuum impregnated with epoxy. The epoxy composition shall be submitted to CLS for review and acceptance.

2.3.4 The copper thermal interlock mounting blocks and copper buses for coil-to-coil and coil-to-power lead connections shall be hard soldered to the conductors. A hard solder shall be selected whose brazing temperature is sufficiently high so that a lower temperature hard solder can be used for repairs if necessary. Proponent shall submit composition of the hard solder to CLS for review and acceptance.

2.3.5 Conductor material shall be OFHC copper, or equivalent.

2.3.6 The pressure drop across any magnet cooling circuit shall be less than 950 kPa.

2.3.7 The total water temperature rise across any magnet shall be less than 5°C.

2.3.8 The coils shall be designed for a nominal operating pressure of 1.2 MPa.

2.3.9 Preliminary coil design parameters can be found in Table 1.

Table 1 Reference design parameters.

	SOA					SOB		
Magnet Type	S windings	X windings (1200 At)	X windings (2400 At)	Y windings	Q windings	S windings	Q windings	
Number of Coils	6	4	2	4	2	6	2	
Number of turns per coil	36	12	24	24	48	36	24	t
Max Current	117.5	111.1	111.1	111.1	15.0	111.1	30.0	A
Amp turns per coil	4230	1333	2666	2666	720	4000	720	A-t
Conductor outer width	4.76	4.50	4.50	4.50	2.04	4.76	4.50	m
Conductor outer height	4.76	4.50	4.50	4.50	2.04	4.76	4.50	m
Conductor cooling channel dia.	3.18	2.50	2.50	2.50	N/A	3.18	N/A	m
Conductor Length per coil	24.0	10.2	18.2	18.2	40.9	24.0	18.2	m
Conductor length per magnet	144	40.8	36.4	72.9	81.8	144	36.4	m
Resistance per coil	29.2	11.9	21.3	21.3	225	29.2	16.1	mΩ
Resistance per magnet	175	47.6	42.5	85.0	450	175	32.2	mΩ
Power per coil	404	147	262	262	50.6	361	14.5	W
Power per magnet	2.42	0.587	0.525	1.05	0.101	2.17	2.90E-02	kW
Voltage Drop per coil	3.44	1.32	2.36	2.36	3.38	3.25	0.483	V
Voltage drop per magnet	20.6	5.29	4.72	9.45	6.75	19.5	0.966	V
Assumed delta T of water	8.0	3.9	14.0	8.2	N/A	7.2	N/A	ºC
Flow rate of water thru coil	0.726	0.537	0.537	0.461	N/A	0.723	N/A	l/min
	0.192	0.142	0.142	0.122	N/A	0.191	N/A	GPM
Total Flow Per Magnet	4.36	2.15	1.07	1.84	N/A	4.34	N/A	l/min
	1.15	0.57	0.28	0.49	N/A	1.15	N/A	GPM
Head loss per coil	457.4	323.3	590.7	454.2	N/A	454.6	N/A	kPa
	66.3	46.9	85.7	65.9	N/A	65.9	N/A	psi

2.3.10 The terminal blocks for the power cable connections shall be attached to the yoke support plates and designed such that the total weight of the power cable is supported by the yoke support.

2.3.11 Buses shall be electrically isolated from the core with US designation NEMA G-10, or equivalent epoxy fibreglass block.

2.4 Yoke

2.4.1 Proponent shall design and fabricate proper turning and handling devices.

2.4.2 Proponent shall design and fabricate all the tooling required to assemble and compress the core.

2.4.3 Proponent shall develop a procedure to fabricate the core. The proponent shall demonstrate to CLS that this procedure is viable by providing other magnet designs that are now in operation or provide sufficient written detail that CLS may review and accept procedure.

2.4.4 Overall physical length, L , of yoke shall be 192.00 ± 1.50 mm. Once the overall length of the yoke has been determined, the magnet-to-magnet tolerance on the yoke length shall be ±0.5 mm.

2.4.5 The assembled lamination-to-lamination stagger tolerance over the pole face shall be less than ±60 μm.

2.4.6 Yoke assemblies shall be glued and mechanically tied together in some fashion.

2.4.7 Material

2.4.7.1 Radiation level measurements of all material heats shall be made and recorded. No detectable radioactive contamination shall be present in steel sheet used for lamination punching.

2.4.7.2 The sheet steel shall have a surface finish sufficient to provide inter-laminar resistivity. The Proponent shall submit the inter-laminar resistivity for CLS review and acceptance.

2.4.7.3 The magnetic properties shall be homogeneous, with low coercivity and high induction values.

2.4.7.4 The chemical analysis after all processing shall have a carbon content less than 0.007%.

2.4.7.5 The Proponent shall supply a certified chemical analysis of the steel.

2.4.7.6 The Proponent shall take 26 Epstein samples (50% parallel and 50% perpendicular to the rolling direction) assembled from strips collected from different heats of the material used for the magnet production. The Proponent shall propose the frequency of the sampling within each heat of material, for CLS review and acceptance.

2.4.7.7 The Proponent shall take magnetic permeability and coercive force measurements using samples from item 2.4.7.6. Results of these measurements shall be submitted to CLS for review and acceptance.

2.4.7.8 Proponent shall keep all samples for possible later re-testing by CLS to verify measured properties.

2.4.7.9 The Epstein samples described in 2.4.7.6 shall be measured at an excitation greater than H_m = 8000 A/m, the magnetic induction B shall be at least 1.79 Tesla. After excitation to H_m = 8000 A/m, the excitation shall be reduced to zero and the coercive force H_c shall be measured and shall not exceed 160 A/m.

2.4.7.10 The variation of coercivity through the whole delivery of steel sheet must stay within ±8 A/m.

2.4.7.11 No mechanical processing of the steel sheet, with the exception of the punching, shall be permitted after the sampling for magnetic measurements.

2.4.7.12 Three (3) strips 20 mm wide by sheet width long shall be cut from both ends and center of a sheet from each steel sheet package used for the quadrupole production.

2.4.7.13 Measurements of the crown and thickness variation across the sheet width shall be made for each of the nine samples referenced in item 2.4.7.12.

2.4.7.14 The thickness variation across the sheet shall not exceed 50 µm.

2.4.7.15 The crown across the sheet shall not exceed 30 µm.

2.4.7.16 The lamination stampings shall be suitable for assembling in stacks with a large (>97%) packing factor.

2.4.7.17 Material from the head, center, and tail of each heat shall be tested for hardness. All material shall have a hardness on the Rockwell scale of B 56 to 90 (HV 90 to 180).

2.4.8 Laminations

2.4.8.1 The pole tip shape should be as detailed in drawing SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).

2.4.8.2 The Proponent shall develop lamination burr requirements, and submit these requirements to the CLS for review and acceptance.

2.4.8.3 The Proponent shall fabricate a sufficient number of magnet laminations to provide for damage, loss or other contingency.

2.5 End Chamfers

2.5.1 The end chamfers shall satisfy the requirements of the field integral distributions defined in Section 2.6. The intent of the end chamfer is to minimize the multipoles above n=3.

2.5.2 The Proponent shall design a method to fabricate the required end chamfers for each sextupole yoke.

2.5.3 The end chamfer may be accomplished in a single cut as shown in drawings SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).

2.5.4 The Proponent shall develop a method for measuring the chamfer dimensions.

2.6 Magnetic

2.6.1 All specifications in this section should be met at the nominal operating field gradient with an excitation efficiency of 97%.

2.6.2 The Proponent shall determine a field resetting algorithm for each function of each family.

2.6.3 The basic design parameters are given in Table 2:

Table 2 Basic Design Parameters.

SOA and SOB			
Aperture, Diameter	D	78	mm
Physical Length	L	192	mm
Maximum Sextupole Gradient	B''	267.8	T/m^2
Maximum Sextupole Gradient Integral	Ideally B'' L	51.42	T/m
Maximum Skew Quadrupole Gradient	B'	0.54	T/m
SOA only			
Maximum Horizontal Corrector (vertical) Field	B_y	0.074	T
Maximum Vertical Corrector (horizontal) Field	B_x	0.086	T

2.6.4 Practically, the maximum field gradient integral for SOA, and SOB shall be

$$\int B''(l)dl = 51.42 \text{ T/m} .$$

The excitation shall be 4230 Amp-turns (or less). The integral shall start and end at points outside the ends of the magnet where the field gradient is less than 0.1% of the maximum field gradient within the interior of the magnet.

2.6.5 For the sextupole field, the good field region shall be defined by a circle of diameter 60 mm centred on the magnet mechanical centre axis.

2.6.6 For a fixed radial position, *r*, within the sextupole good field region, the magnetic field, including end effects, shall meet the following criterion:

$$-0.01 < \frac{\sum_{n=4}^{\infty} r^{n-1} \int B_n(l)dl}{r^2 \int B_3(l)dl} < 0.001$$

where B_n is the nth multipole (Note: $B_3 \equiv B''$). In other words, the integrated multipole fields (sum of all multipoles beyond n=3) shall be between –1% and 0.1% of the integrated sextupole field, within the good field region of the sextupole. Furthermore, the dipole field, B_1, should be less than 1.0% of the sextupole field at r = 30 mm, and the quadrupole field, B_2, at r = 30 mm, should be less than 0.1% of the sextupole field at r = 30 mm.

2.6.7 For the horizontal corrector field, the good field region shall be defined by a circle of diameter 35 mm centred on the magnet mechanical centre axis.

2.6.8 For a fixed radial position, *r*, within the corrector good field region, the magnetic field, including end effects, shall meet the following criteria:

$$-0.01 < \frac{\sum_{n=2}^{\infty} r^{n-1} \int B_n(l)dl}{\int B_1(l)dl} < 0.07$$

where B_n is the nth multipole (Note: $B_2 \equiv B_y$). In other words, the integrated multipole fields (sum of all multipoles beyond n=1) shall be between –1% and 7% of the integrated corrector field, within the good field region of the corrector.

2.6.9 For the vertical corrector field, the good field region shall be defined by a circle of diameter 35 mm centred on the magnet mechanical centre axis.

2.6.10 For a fixed radial position, *r*, within the corrector good field region, the magnetic field, including end effects, shall meet the following criteria:

$$-0.07 < \frac{\sum_{n=2}^{\infty} r^{n-1} \int B_n(l)dl}{\int B_1(l)dl} < 0.01$$

where B_n is the nth multipole (Note: $B_2 \equiv B_x$). In other words, the integrated multipole fields (sum of all multipoles beyond n=1) shall be between –7% and 1% of the integrated corrector field, within the good field region of the corrector.

2.6.11 For the skew quadrupole field, the good field region shall be defined by a circle of diameter 35 mm centred on the magnet mechanical centre axis.

2.6.12 For a fixed radial position, *r*, within the skew quadrupole good field region, the (skew) magnetic field, including end effects, shall meet the following criteria:

$$-0.25 < \frac{\sum_{n=3}^{\infty} r^{n-1} \int B_n(l)dl}{r \int B_2(l)dl} < 0.05$$

where B_n is the nth multipole (Note: $B_2 \equiv B'$). In other words, the integrated (skew) multipole fields (sum of all multipoles beyond n=2) shall be between –25% and 5% of the integrated skew quadrupole field, within the good field region of the skew quadrupole. The (skew) dipole field is expected to be negligible.

2.6.13 Proponent shall design and fabricate compensated rotating coils to make the required magnetic measurements.

3. SAFETY AND ENVIRONMENTAL

3.1 Laminations

All sheet steel shall be packaged to protect the sheets against moisture during shipping and storage.

3.2 Assembly

3.2.1 The coils of each assembled magnet shall be blown out to insure there is no water remaining in the coils immediately after testing.

3.2.2 The assembled magnets shall be packaged to protect the magnets against environments encountered during shipping and storage.

3.2.3 The nominal operating temperature of the magnet cores is expected to be between 20°C and 40°C. The expected normal ambient temperature of the tunnel is 27°C ± 0.1°C.

3.2.4 The magnets shall be able to withstand a relative humidity range of 0 % to 90 %. The expected relative humidity limits under operation are from 25% during the winter months and to a maximum of 50% during the summer months.

4. APPLICABLE CODES, STANDARDS AND PROCEDURES

Not Applicable

5. QUALITY ASSURANCE

The Proponent shall maintain and apply a quality assurance program compliant with ISO-9001 for the design, manufacture, and testing of all magnets.

6. INSPECTION, TESTING AND COMMISSIONING

The inspection sheets shall be filled out, signed, and dated by the technicians performing the tests and inspections listed below. The completed inspection sheet for each coil, yoke, and assembly shall be signed and dated by the technician supervisor.

The following inspections, tests, and commissioning shall be in addition to those identified in CLS Specification 8.4.31.1, CLS General Magnet Specification [3], dated 1999-12-01 (previously known as CLS31-001 Rev 1).

6.1 Laminations

6.1.1 Proponent shall develop an inspection sheet for the laminations. This sheet shall be reviewed and accepted by the CLS.

6.1.2 The information contained within the inspection sheet shall include at least the following:

- Steel sheet package/heat number
- Lamination punching serial number
- Burr size(s) if exceed the tolerance, its (their) location on the lamination
- Gap dimensions (dimensions between the yoke pole tips)
- Names of technician(s) inspecting
- Date of Inspection
- All material test results in section 2.4.7

6.1.3 Proponent shall file the original completed and signed inspection sheet..

6.1.4 A copy of the original completed and signed inspection sheet for all inspected laminations shall be delivered to CLS.

6.1.5 Steel shall be stable with respect to time in both coercivity and permeability.

6.1.6 Accelerated aging of steel used for laminations shall be done to ensure no substantial change in magnet properties is observed.

6.1.7 The laminations shall be periodically inspected in order to ensure adherence to both dimensional and burr tolerances.

6.1.8 Stamped laminations shall adhere to the burr requirements developed by the Proponent. Burr inspections shall occur at frequencies determined by the Proponent, however not less than one lamination per quantity of sheets required in three (3) yoke assemblies shall be inspected. Should the burr exceed the specified requirement, all laminations punched after the last inspection shall either be rejected or de-burred and the die and punch shall be re-sharpened.

6.1.9 Three sample laminations shall be inspected after each die or punch re-sharpening to ensure specification tolerances are met. All sample laminations and inspection records shall be forwarded to CLS.

6.1.10 The first lamination stamped from the first sheet of each batch of steel shall be inspected to determine the gap size prior to stamping laminations from that heat of material. This gap shall fall within the specified tolerances of the fabrication drawings developed by the Proponent.

Rational: The gap between the poles is critical to the field quality and the reproducibility of the excitation from magnet to magnet. The gap size of the lamination may be affected by the release of rolling stress locked into the steel sheet material. This stress may vary between various batches of material used for the stamping.

6.1.11 The Proponent shall develop a pre-punch process to relieve the stresses, if the inspection in line 6.1.10 indicates the gap tolerance is not met.

6.1.12 The Proponent shall determine when periodic (after fabricating specified number of laminations) inspections of laminations for compliance to drawing tolerances shall occur, and submit this to CLS for review and acceptance. If inspection determines the laminations are out of tolerance, fabrication shall stop until appropriate repairs or adjustments are made to the die set and a new set of sample laminations are inspected and approved. All sample laminations and inspection reports shall be delivered to CLS for verification of dimensions.

6.2 End Chamfer

6.2.1 Proponent shall develop an inspection sheet for the end chamfers. This sheet shall be reviewed and accepted by the CLS.

6.2.2 The information contained within the inspection sheet shall include at least the following:

- Yoke serial number and left or right end when looking at the magnet from the service connections side of the magnet.
- End chamfer measurement data
- Names of technician(s) inspecting
- Date of Inspection

6.2.3 Proponent shall file the original completed and signed inspection sheet.

6.2.4 A copy of the original completed and signed inspection sheet for all inspected laminations shall be delivered to CLS.

6.2.5 End chamfer dimensions shall be measured. If the chamfer dimensions exceed the desing tolerance, the chamfer shall be re-machined or rejected. The measured data shall be recorded in the inspection sheet.

6.3 Coil

6.3.1 Proponent shall develop an inspection sheet for the coil. This sheet shall be reviewed and accepted by the CLS.

6.3.2 The information contained within the inspection shall include at least the following:

- Coil Serial Number
- Results of visual inspection, with technician name and date

- Measurement & Inspection results, with responsible technician name and date
- Electrical Test Results, with responsible technician name and date
- Hydraulic measurement Test Results, with responsible technician name and date
- Names of technicians winding the coil and date
- Names of technicians vacuum impregnating the coil with epoxy, and date
- Names of technicians attaching interlock and terminal blocks and dates
- Name of supervising technician approving the magnet for delivery and date.

6.3.3 Proponent shall file the original completed and signed inspection sheet.

6.3.4 A copy of the original completed and signed inspection sheet for the coil shall be delivered to CLS with the magnet.

6.4 Assembly

6.4.1 Proponent shall develop an inspection sheet for the magnet assembly. This sheet shall be reviewed and accepted by the CLS.

6.4.2 The information contained within the inspection shall include at least the following:

- Magnet Assembly Serial Number
- Core Serial Number
- Serial Numbers of Coils
- Electrical Test Results
- Measurement Test Results
- Hydraulic measurement Test Results
- Names of technicians installing coils and date
- Names of technicians assembling bus bars and interlocks, and date
- Names of technicians performing the magnetic measurements and dates
- Name of supervising technician approving the magnet for delivery and date.

6.4.3 Magnetic measurements of quadrupole magnets shall proceed as soon as a production magnet is assembled. The backlog of unmeasured magnets shall be no greater than 5 magnets.

6.5 Magnetic Measurements

6.5.1 Magnetic measurements shall be made on all magnets.

6.5.2 Proponent shall use a rotating coil to make magnetic measurements.

6.5.3 Proponent shall provide supporting documentation on the details of the measurement coil engineering design, including the positions of the various coil bundles and the number of turns in each bundle. The computed dipole and quadrupole absolute sensitivity (using theoretical dimensions) and the relative sensitivities to the error multipoles in the bucked configuration shall be tabulated. Sketches shall be included which describe the orientation of the coil drive axis, identify the coordinate axes of the measurements with respect to the magnet features (e.g. power buss location) and the rotation direction of the measurement coil.

6.5.4 Proponent shall measure the integrated multipole error and determine the offset of the magnetic center from the mechanical center

6.5.5 Magnetic measurement data shall be referenced by the magnet identification serial number.

6.5.6 Magnetic measurement data sheet shall include:

- Magnet Serial Number
- Date and Time (year/month/day/hour/min) measurement was performed.
- The ambient temperature (°C) during the measurement.
- Names of the technicians performing the measurement.
- Results of Uncompensated Measurements:
    - Measurement current. Drift counts. Normalizing radius. Dipole and quadrupole integrator counts, integrated fields (using computed coil sensitivities), their absolute

phases with respect to coil horizontal axis at start of rotation. X, Y and magnitude of the offset of magnetic axis from the coil axis.

- Results of Compensated Measurements:
  - Measurement Current. Drift counts. Quadrupole bucking ratio. Normalizing radius. Integrator counts, computed multipole normalized to the fundamental quadrupole and phases relative to the quadrupole zero phase on the positive magnet x-axis for all multipole error terms from n=3 to n=18
- Name of supervising technician approving the magnetic measurements.

6.5.7 All measurement results shall be filed in hardcopy, on magnetic media, and archived at the Proponent's location in duplicate. The Proponent shall store the raw unbucked and bucked integrator output before performing Fourier analysis.

6.5.8 Electronic versions of the measurement results shall include:

6.5.8.1 Header line(s) containing measurement units, location, name of technician performing measurement, and name of supervising technician.

6.5.8.2 Header line(s) shall be designated with a starting symbol, "#".

6.5.8.3 Each data line shall contain the integrator output, excitation current, temperature, date, and time.

6.5.9 One set of measurements in hardcopy and an electronic copy on magnetic media shall be sent to CLS for after assembly and measurement of no more than six production magnets. More frequent data transfer is encouraged.

6.5.10 Proponent shall file the original completed and signed inspection sheet..

6.5.11 A copy of the original completed and signed inspection sheet for the assembly shall be delivered to CLS with the magnet.

6.5.12 Upon assembling the first production magnet of SOA, measurements shall be made and data sent to CLS for review and acceptance prior to machining the chamfers on the remaining magnets.

6.5.13 The rotating coil housing shall be aligned within the magnet bore such that the rotating axis is within a 0.025 mm radius of the magnet mechanical axis

6.5.14 Magnetic measurements shall be in reference to the origin, as defined in 2.2.4.

6.5.15 Magnetic measurements shall be taken in a reasonably temperature-controlled environment, maintained at 23°± 2°C. Each magnet shall be acclimatized to the environment temperature.

6.5.16 Ambient temperature measurements shall recorded with 3 significant figures (0.1°C). The temperature measurement device shall be calibrated prior to and after all measurements have been taken. The calibration data shall be kept on record, and a copy sent to CLS.

6.5.17 Each magnet shall be measured with the polarity as detailed in drawings SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).

6.5.18 Each magnet shall be conditioned prior to magnetic measurements. Reconditioning is not required for additional measurements.

6.5.19 Each magnet shall be conditioned using the Proponent's resetting procedure prior to adjusting the current to the measurement levels. The current rate of rise and return to zero shall be approximately linear and shall take no less than 10 seconds per cycle.

6.5.20 The Proponent shall develop, and implement a procedure for measuring the integrated field gradient integral on all production magnets. This procedure shall be reviewed and accepted by the CLS prior to magnet fabrication.

6.5.21 Proponent shall make uncompensated and compensated measurements (with a minimum of 4 excitations) to sufficiently establish the excitation curve for each function of each magnet. The Proponent shall submit their measurement program for CLS review and acceptance.

6.5.22 Current measurements shall be made to at least five significant figures (0.01 Amps).

6.5.23 Proponent shall determine the good field region along the magnet axis for each magnet function, of one production magnet from each family.

6.5.24 Proponent shall notify CLS immediately, magnetic measurements, or multipole content do not meet the accepted magnetic tolerances. In this case the following procedures shall be taken.

6.5.24.1 Proponent shall perform a detailed inspection of the core to ensure mechanical tolerances have been satisfied.

6.5.24.2 Proponent shall provide CLS with all measurement data and plans for any corrections as soon as possible.

6.5.24.3 Proponent shall implement changes, and remeasure magnet.

6.5.24.4 Items 6.5.24.1 through 6.5.24.3 shall be repeated until the magnet meets required tolerances.

6.5.24.5 All corrections and resulting measurements shall be noted in the magnet assembly inspection sheet for the respective magnet assembly.

6.5.24.6 CLS shall be notified promptly if corrections do not result in magnets that satisfy the magnetic tolerances, and plans and procedures for necessary correction of production procedures shall be mutually negotiated between the Proponent and CLS. Problems that are not easily corrected may require rejection of the magnet in question, or some of it's components and/or temporary suspension of a portion of the production effort until satisfactory corrective plans are developed.

7. RELIABILITY AND MAINTAINABILITY

7.1 The expected lifetime shall be greater than 25 years.

7.2 Water connections shall be readily accessible for maintenance.

8. LAYOUT

8.1 A preliminary design can be found in drawings found in reference [5].

8.2 Four lifting lugs are required at points noted in drawings found in reference [5].

9. OTHER REQUIREMENTS AND CONSTRAINTS

9.1 Tolerances, where not defined or where difficult to achieve, are subject to negotiation.

9.2 Labelling & Colours:

9.2.1 Component identification and colour

9.2.1.1 All sextupoles shall be painted dark red. A color sample shall be submitted to CLS for review and acceptance.

9.2.1.2 All assemblies shall be labelled with a permanent unique serial number following the form:

SR1-SO[family A, or B]-##

where ## is the production serial number (01-24, or 01-12 respectively).

9.2.1.3 All assemblies shall be affixed with a nameplate with the following format:

CLS Sextupole Magnet

Serial No.:
Net Weight (kg):
Cooling & Power Data Dwg:
Date:
Manufacturing Company Name

9.2.1.4 All lettering on nameplate shall be in 14 point font size.

9.2.2 The position of the nameplate shall not interfere with magnet operation.

9.3 Preparation for shipment and delivery.

9.3.1 The coils of each assembled magnet shall be blown out to insure there is no water remaining in the coils.

9.3.2 No more than one magnets shall be packed in a shipping crate.

9.3.3 Crates shall be designed such that it can be moved using a standard handling device (forklift or pallet jack).

9.3.4 The magnet shall be wrapped or covered to protect it from moisture within the shipping crate.

10. REFERENCES

[1] L.O. Dallin, Canadian Light Source, Saskatoon, SK. CLS Design Note 5.2.31.2, Synchrotron Light Source Magnets, 2000-12-11.

[2] L.O. Dallin, Canadian Light Source, Saskatoon, SK. CLS Design Note 5.2.69.2, Canadian Light Source Main Ring Lattice, 2000-12-11.

[3] D.S. Lowe, Canadian Light Source, Saskatoon, SK. CLS Specification 8.4.31.1, CLS General Magnet Specification, 2000-12-15. (Previously numbered as CLS31-001 Rev. 1)

[4] D.S. Lowe, Canadian Light Source, Saskatoon, SK. CLS Specification 0.4.1.1 Rev. 1, CLS Documentation Specification, 2000-12-15. (Previously numbered as CLS01-001 Rev. 1)

[5] Canadian Light Source, Saskatoon, SK. CLS Drawings SR1/ME/MAG/0037700 Rev A (SOA), SR1/ME/MAG/0037900 Rev A (SOB).