CLS SR1 ORBIT CORRECTOR MAGNET SPECIFICATION

CLS 5.8.31.4 Rev O

2001-12-13

Canadian Light Source
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REVISION HISTORY

Revision.	Date	Description	By
A	13 August 2001	Draft	Les Dallin
B	28 November 2001	Update	Daniel S. Lowe
C	12 December 2001	Update from reviewer #2	Les Dallin
O	13 December 2001	(Rev B comments) Issued for release	Les Dallin

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1. INTRODUCTION

1.1. Purpose

This document will specify the requirements for the Canadian Light Source (CLS) storage ring (SR1) orbit corrector magnets (orbit correctors).

1.2. Scope

The Canadian Light Source requires twenty-four orbit correctors, to be designed, fabricated, tested and delivered to the CLS site. Each magnet will run with four quadrant DC power supplies with capability up to 100 Hz operation. Power supplies will be supplied by CLS. The yoke shall be laminated steel.

This specification details the requirements for the design, fabrication, and supply of the CLS SR1 orbit correctors. This work includes, but is not limited to:

- All tooling
- Materials
- Equipment
- Commercial components
- Detailed drawings
- Fabrication
- Assembly
- Testing & Inspections
- QA/QC documentation
- Delivery to site

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 is a 3rd generation synchrotron light source, which will produce a high intensity source of infrared, visible, ultraviolet and x-ray radiation.

This facility requires twenty-four orbit correctors to be designed and manufactured for installation by owner into the CLS storage ring. One prototype magnet is also required. The storage ring will be capable of circulating electrons with energies of up to 2.9 GeV.

The following items provide some background to this specification.

- CLS 5.2.31.4 Rev. A (formerly 2.1.48) – L.O. Dallin, XY Orbit Correctors[1]
- CLS 5.2.69.4 Rev. A (formerly 2.1.47) – L.O. Dallin, Dynamic Orbit Correction[2]
- CLS 8.2.69.1 Rev. O (formerly 2.1.20.B) – L.O. Dallin, CLS Lattice Performance Analyses[3]
- CLS 8.4.30.1 Rev.1 – N. G. Johnson, CLS Magnet Power Supply Specification
- Reference drawings[4].

2. REQUIREMENTS

2.1. Functional

2.1.1. Proponent shall provide evidence to show that their proposal and designs meet all requirements in this document.

2.1.2. All requirements shall, in addition, conform to CLS General Magnet Specification 8.4.31.1 Rev 0. Specifications within this document take precedence over CLS General Magnet Specification 8.4.31.1.

2.1.3. Prior to commencement of fabrication, the Proponent shall issue for review and acceptance by CLS all drawings and procedures developed by the Proponent. The Proponent shall also supply the B-H curve for the proposed steel to CLS for review and acceptance, prior to fabrication material purchase.

2.1.4. Proponent shall demonstrate that the Proponent has access to the appropriate facilities to carry out the magnetic measurements.

2.2. Assembly

2.2.1. Corrector magnet assembly shall consist of the following major components:

- Yoke
- Six (6) 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

2.2.2. Electrical terminal blocks shall be manufactured from OFHC copper.

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

2.2.4. Buses shall be electrically isolated from the yoke. Proponent shall specify high potential leakage test procedure for CLS review and acceptance.

2.2.5. Water supply and return fittings shall be clearly labelled to prevent mis-connections.

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

2.2.7. Each magnet shall have a support frame that allows the magnet to be directly mounted on a precision-machined support girder. The face of the girder is located 366.3mm below the ideal beam centre. The magnet shall be designed such that it may be located after the vacuum chamber is in place. Figure 1 illustrates the relative layout of the magnet, vacuum chamber, and support girder.

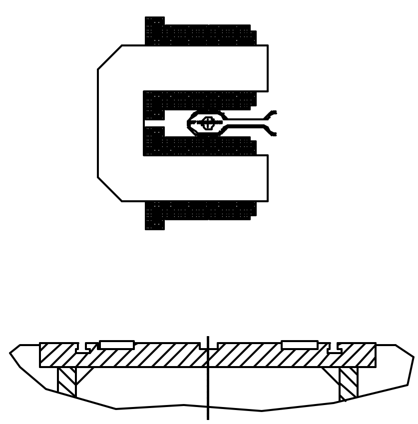

Figure 1 Illustration of corrector magnet, vacuum chamber and support girder.

2.2.8. 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.

2.2.9. 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.

2.3. Fiducials

2.3.1. The magnet shall have 6 fiducial points accurately referenced to the entrance and exit points on the ideal orbit at the physical end of the yoke. The fiducial points shall encompass the volume of the magnet.

2.3.2. The fiducials shall be located using a right hand Cartesian co-ordinate system (X,Y,Z), with the origin located at beam centre in the plane of the pole face at the end with service connections, as shown in drawing SR1/ME/MAG/0036904 Rev C.

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

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

2.4. Coils

2.4.1. Each magnet contains six (6) coils.

2.4.2. The four coils for the vertical corrector are connected in series.

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

2.4.4. Conductor material shall be OFHC copper, or equivalent.

2.4.5. Magnet coils shall have parallel water-cooling circuits for each coil.

2.4.6. The pressure drop across any coil shall be less than 800 kPa.

2.4.7. The temperature rise across any coil cooling circuit shall be less than 6°C.

2.4.8. The coil shall be designed for a nominal operating pressure of 1.0 MPa.

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

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

2.4.11. The terminal blocks for the power cable connections shall be attached to the yoke and designed such that the yoke supports the total weight of the power cable.

2.4.12. Each coil shall have 2 thermal switches mounted on the water return side of the coil.

2.4.13. The copper thermal interlock mounting blocks and copper buses for 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. CLS shall be informed of the composition of the hard solder to be used for possible later repairs at CLS.

2.5. Yoke

2.5.1. The magnet yoke shall be made of laminated steel.

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

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

2.5.4. 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 the procedure.

2.5.5. Overall physical length, L (Figure 1), of yoke shall be 150.0 ± 0.50 mm.

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

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

2.5.8. Material

2.5.8.1. The lamination thickness shall be suitable for corrector operation with AC frequencies up to 100 Hz. A thickness of 0.35 mm or less is required.

2.5.8.2. Inter-lamination insulation shall be used to prevent eddy current losses during AC operation.

2.5.8.3. The silicon content of the steel should be chosen to optimize the permeability at half the maximum field value (0.045 T). As well, the silicon content should reduce the AC losses at 100 Hz. This suggests that non-oriented high silicon steel (~3%) is appropriate. Proponent shall consult with CLS on the choice of steel.

2.5.8.4. 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.

2.5.8.5. 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.

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

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

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

2.5.8.9. 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.

2.5.8.10. The Proponent shall take magnetic permeability and coercive force measurements using samples from item 2.5.8.9. Results of these measurements shall be submitted to CLS for review and acceptance.

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

2.5.8.12. The Epstein samples described in 2.5.8.9. 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.

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

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

2.5.8.15. 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 corrector production.

2.5.8.16. Measurements of the crown and thickness variation across the sheet width shall be made for each of the nine samples referenced in 2.5.8.15.

2.5.8.17. The thickness variation across the sheet shall not exceed 5% of the lamination thickness.

2.5.8.18. The crown across the sheet shall not exceed 3% of the lamination thickness.

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

2.5.8.20. 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).

2.6. Magnetic (DC operation)

2.6.1. All specifications shall be met at the maximum operating field with an excitation efficiency of 96%.

2.6.2. The basic design parameters are given in Table 1 and shown in Figure 2.

Table 1. Basic Design Parameters

Number of magnets	24			
Length of yoke, L	0.150			m
Full length including coils, D	0.282			m
Full pole gap (yoke), G	0.108			m
Full gap (between coils), g	0.044			m
Maximum X or Y kick (at 2.9 GeV)	1.4			mrad
Maximum Field strength at centre B_y	0.090			T
Maximum Field strength at centre B_x	0.090			T
Magnet length	0.15			m
Magnet gap (yoke)	108			mm
Magnet gap (between coils)	44			mm
Good field width (1%)(B_y)	±40			mm
Good field width (1%)(B_x)	±20			mm
Coil Function	Horizontal B_y	Vertical B_x	Vertical Middle B_x	
Number of coils	2	2	2	
Number of turns per coil	24	39	36	T
Max current	180	180	180	A
Amp turns per coil	4320	7020	6480	A-T
Conductor outer width	6.48	6.48	6.48	mm
Conductor outer height	6.48	6.48	6.48	mm
Conductor corner radius	1.0	1.0	1.0	mm
Conductor cooling channel diameter	3.18	3.18	3.18	mm
Conductor length per coil	17.287	24.982	23.167	m
Conductor length per magnet	34.574	49.964	46.334	m
Resistance per coil	9.3	13.5	12.5	mΩ
Resistance per magnet	18.7	27.0	25.0	mΩ
Power per coil	302	437	405	W
Power per magnet	605	874	810	W
Voltage drop per magnet	3.36	4.86	4.5	V
Assumed ΔT of water	3.28	5.96	5.29	^{o}C
Flow rate of water thru coil	1.32	1.06	1.10	L/min
	0.35	0.28	0.29	usGPM
Total flow per magnet	2.65	2.12	2.20	L/min
	0.7	0.56	0.58	usGPM
Head loss per coil	917	917	917	kPa
	133	133	133	psi

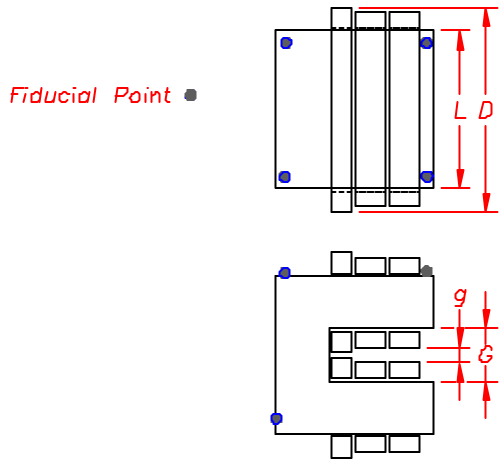

Figure 2. Orbit Corrector Schematic

2.6.3. Practically, for operation at 2.9 GeV, the magnets shall meet the following criteria at maximum excitation. The field integral along the beam axis (l) shall be

$$\int B_y(l,0,0)dl = B_y(0,0,0)l_0 = 0.0135 \text{ T}\cdot\text{m},$$

$$\int B_x(l,0,0)dl = B_x(0,0,0)l_0 = 0.0135 \text{ T}\cdot\text{m},$$

where the field integral includes the fringe fields at both ends of the magnet to a point where $B(l,0,0)$ is 1.0% of the central field. The field integral can be made exactly the above value by adjusting the excitation current. l_0 is the effective length on orbit and B_y(0,0,0) is the central field.

2.6.4. For the vertical field, B_y, the good field region is defined to satisfy the following criteria (over the same limits of integration and for any fixed x position).):

$$0.99 < \frac{\int B_y(l,x,0)dl}{B_y(0,0,0)l_0} < 1.01.$$

2.6.5. This good field region in the horizontal direction (x) shall be determined. It is expected that the good region should extend from –40 mm to 40 mm.

2.6.6. For the horizontal field, B_x, the good field region is defined to satisfy the following criteria (over the same limits of integration and for any fixed x position):

$$0.99 < \frac{\int B_x(l,x,0)dl}{B_x(0,0,0)l_0} < 1.01,$$

2.6.7. This good field region in the horizontal direction (x) shall be determined. It is expected that the good region should extend from –20 mm to 20 mm.

2.7. Magnetic (AC operation)

2.7.1. AC operation will be applied to both horizontal and vertical fields.

2.7.2. AC operation will be superimposed on the DC operation.

2.7.3. Four quadrant current regulated power supplies will be used. These power supplies will be provided by CLS.

2.7.3.1. Power supplies will be adjustable from maximum rated output, through 0, to maximum rate output at the opposite polarity.

2.7.3.2. 100 Hz operation is required and the effects of magnet inductance are significant.

2.7.3.3. The basic power supply specifications and corrector parameters are given in Table 2.

2.7.3.4. It is expected that the both horizontal and vertical correctors will be capable of producing a field of 0.0045 T at 100 Hz.

Table 2. Corrector Power Supply Specifications and Corrector Parameters

Power Supply Specifications	X (Y) Orbit Corrector
Type (Unipolar, Bipolar, Four Quadrant)	Four Quadrant
Output Voltage Range (V)	±14 (±17)
Output Current Range (A)	±180 (±180)
Regulation	10 ppm
Bandwidth	
3 dB	5 Hz
20 dB	50 Hz
Control	Analog setpoint / feedback, Digital status / control
Output cable size	250 MCM
Special Requirements	Option to increase small signal bandwidth to 100 Hz, 5% Full Scale Output
Corrector Parameters (Loads)	
Nominal load resistance (ohms)	0.0187 (0.052)
Nominal load inductance (H)	0.0015 (0.0010)

3. SAFETY AND ENVIRONMENT

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

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

3.1.3. The nominal operating temperature of the magnet cores is expected to be between 20°C and 40°C. The normal ambient temperature of the SR1 tunnel is 27 °C. The expected temperature stability of the tunnel will be better than 1 °C during normal operation.

3.1.4. Cooling water will be supplied at 26 °C ± 1 °C

3.1.5. The components shall be able to withstand a relative humidity range of 0% to 95%. The expected relative humidity limits under normal operation are from 25% to 50%.

3.1.6. All components shall be designed for operation in a radiation environment. The vendor shall avoid materials that are subject to damage by ionizing radiation or provide adequate shielding incorporated into the design to allow for long service life of the component.

3.1.7. In the tunnel environment there will be a small amount of production of radioactive air and noxious gases. These are estimated to be:

1. N-13, O-15 and C-11: 0.0002 Bq/cc.
2. Ozone: 5.6×10^{8} mol/cc.
3. Nitrogen dioxide: 2.7×10^{8} mol/cc.
4. Nitric acid: 0.8×10^{8} mol/cc.

4. APPLICABLE CODES, STANDARDS AND PROCEDURES

None

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 2.5.8.

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 four yoke assembly 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 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. Coil

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

6.2.2. 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.

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

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

6.3. Assembly

6.3.1. An inspection sheet for each magnet assembly shall be designed by the Proponent. 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:

- 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. Magnetic Measurement (DC operation)

6.4.1. Magnetic measurements (DC operation) shall be made on all magnets. Measurements on the prototype magnet shall be used to optimize the coil locations.

6.4.2. Magnetic measurement data sheet shall include:

- Dates and Times (year/month/day/hour/sec) measurements were performed.
- The ambient temperature (°C) during the measurements.
- Names of the technicians performing the measurements.
- Name of supervising technician approving the magnetic measurements.

6.4.3. All measurement results shall be filed in hardcopy, on magnetic media, and archived at the Proponent’s location in duplicate.

6.4.4. Electronic versions of the measurement results shall include:

- Header line(s) containing measurement units, location, name of technician performing measurement, and name of supervising technician.
- Header line(s) shall be designated with a starting symbol, “#”.
- Each data line shall contain the field measurement, excitation current, x, y, z location, temperature, date, and time.

6.4.5. One set of measurements in hardcopy and an electronic copy on magnetic media shall be sent to CLS for review and acceptance after assembly and measurement.

6.4.6. The original completed and signed inspection sheet shall be kept on file by the Proponent.

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

6.4.6.2. Magnetic measurements shall be in reference to the origin, as defined in 2.3.2.

6.4.6.3. Magnetic measurements shall be taken in a temperature-controlled environment at 27 °C.

6.4.6.4. 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.

6.4.6.5. The Proponent shall develop, document, and implement procedures to measure the field integral along the corrector axis at the maximum field strength (0.090 T) for both the vertical and horizontal fields. The Proponent shall indicate the relative accuracy and reproducibility for these measurements. This procedure shall be reviewed and accepted by the CLS prior to magnet fabrication.

6.4.6.6. The Proponent shall develop, document, and implement procedures to measure the good field region at the maximum field strength (0.090 T) for both the vertical and horizontal fields. The Proponent shall indicate the relative accuracy and reproducibility for these measurements. This procedure shall be reviewed and accepted by the CLS prior to magnet fabrication.

6.4.6.6.1. Measurements on the prototype magnet shall be used to optimize the location of the coils for the vertical corrector (horizontal field). The position of these coils shall be adjusted to optimize the good field region.

6.4.6.7. Proponent shall determine the field excitation curve for the magnets.

6.4.6.8. Current measurements shall be made to at least four significant figures (0.1 Amps).

6.4.7. Field measurement instrument specifications shall be provided to CLS for review and acceptance prior to magnet fabrication.

6.5. Magnetic Measurement (AC operation)

6.5.1. Magnetic measurements for AC operation are optional, however:

6.5.2. Proponent shall indicate capability (if any) for making measurements up to 100 Hz operation.

7. RELIABILITY AND MAINTAINABILITY

7.1.1. The expected lifetime shall be greater than 25 years.

7.1.2. Water connections shall be readily accessible for maintenance.

8. OTHER REQUIREMENTS AND CONSTRAINTS

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

8.1.2. Labelling & Colours:

8.1.2.1. The correctors shall be affixed with a nameplate with the following format:

CLS SR1 Orbit Corrector Magnet

Net Weight.:
Design Flow Rate (l/s)
Inner: Middle: Outer:
Design Pressure Drop (kPa)
Inner: Middle: Outer:
Design Voltage Drop (V):
X: Y:
Design Current (A):
X: Y:
Date:

Manufacturing Company Name

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

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

8.1.2.4. Colour shall be RAL 5002 Ultramarine Blue.

8.1.3. Shipment and delivery preparation.

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

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

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

9. REFERENCE MATERIAL

[1] L. O. Dallin, "XY Orbit Correctors", CLS Design Note 5.2.31.4 Rev. A (formerly 2.1.48), May 30, 2000

[2] L. O. Dallin, "SR1 Dynamic Orbit Correction", CLS Design Note 5.2.69.4 Rev. A (formerly 2.1.47), May 30, 2000

[3] L. O. Dallin, "CLS Lattice Performance Analyses", CLS Design Note 8.2.64.1 Rev. O (formerly 2.1.20.B), November 27, 2000

[4] Canadian Light Source, Saskatoon, SK. CLS Drawing SR1/ME/MAG/0036904 Rev C "SR1 Horizontal/Vertical Orbit Corrector Magnet"

[5] D.S. Lowe, "CLS General Magnet Specification", CLS Specification 8.4.31.1 Rev 0 (formerly CLS31-001 Rev. 1), December 15, 2000.

[6] D.S. Lowe, "CLS Documentation Specification", CLS Specification 0.4.1.1 Rev. 2, December 15, 2000.

[7] N. G. Johnson, "CLS Magnet Power Supply Specification", CLS Specification 8.4.30.1 Rev. 1, June 27, 2001.