CLS Superconducting Cavity Niobium Specification

CLS2.40.32.001 Rev. 1

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REVISION HISTORY

Revision.	Date	Description	By
A	20 April 2000	Draft	R. Mark Silzer.
0	9 May 2000	Original Issue	R. Mark Silzer
1	06 July 2000	Change yield stress specification on larger thickness material	R. Mark Silzer

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1 INTRODUCTION

1.1 Purpose

This document will specify the requirements for the Niobium used at the Canadian Light Source (CLS) for the manufacture of superconducting (SC) cavities.

1.2 Scope

This specification covers unalloyed annealed Niobium sheet material. This specification will include, but not be limited to:

- Fabrication
- Testing and Inspection
- QA/QC documentation

1.3 Background

The Canadian Light Source, CLS, is a national facility in the initial phase of 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.

The CLS will be utilizing SC technology in its machine operation. Initially, a SC cavity based on the Cornell B-factory cavity design will be used in the 2.9 GeV storage ring to make up for beam energy losses as well as to ensure beam stability and adequate beam lifetime. A second spare cavity will also be located on site. This technical specification applies to all niobium sheet used for the production of SC cavities for the CLS.

2 NIOBIUM REQUIREMENTS

2.1 Functional Requirements

2.1.1 The dimensions of the Niobium parts required for one SC cavity are specified in Table 1. Note that item 17 is a ring with outer and inner diameters of 290 mm and 230 mm respectively.

Table 1: Technical Specification Materials Lists

Item #	Part Name	Quantity (per cavity)	Thickness (mm)	Tolerance (mm)	Width (mm)	Tolerance (mm)	Length (mm)	Tolerance (mm)	Volume/cav. (cu mm)	Weight/cav. (kg)
RRR=250 Ultra Pure Niobium Material										
1	RBT Top	1 each	3	±0.12	258	±1.5	477	±1.5	369198	3.16
2	RBT Bottom	1 each	3	±0.12	258	±1.5	477	±1.5	369198	3.16
3	Inner WG	1 each	3	±0.12	320	+1.5,-0	430	+1.5,-0	412800	3.54
4	Outer WG	1 each	3	±0.12	490	+1.5,-0	430	+1.5,-0	632100	5.42
5	FBT Shell	1 each	3	±0.12	500	±1.5	780	±1.5	1170000	10.03
6	FBT Flutes	4 each	3	±0.12	360	±1.5	200	±1.5	864000	7.40
7	Thick WG Sides	1 each	12	+1.5,-0	260	±1.5	490	±1.5	1528800	13.10
8	Coupler Block	1 each	35	+0.5,-0	120	±1.5	445	±1.5	1869000	16.02
	Flatness of Items 7 and 8 better than ± 1 mm							TOTALS	7215096	61.83
RRR=400 preferred RRR=280 guaranteed Ultra Pure Niobium Material										
Item #	Part Name	Quantity (per cavity)	Thickness (mm)	Tolerance (mm)	Width (mm)	Tolerance (mm)	Length (mm)	Tolerance (mm)	Volume/cav. (cu mm)	Weight/cav. (kg)
9	Spun Cups	2 each	3	±0.12	705	+3,-0	705	+3,-0	2982150	25.56
99.85 % Pure Niobium Material										
Item #	Part Name	Quantity (per cavity)	Thickness (mm)	Tolerance (mm)	Width or diameter (mm)	Tolerance (mm)	Length (mm)	Tolerance (mm)	Volume/cav. (cu mm)	Weight/cav. (kg)
10	Strut Link	2 each	3	±0.12	50	±1	160	±1.5	48000	0.41
11	Strut	2 each	3	±0.12	50	±1	205	±1.5	61500	0.53
12	WG Stiffener	2 each	3	±0.12	100	±1.5	445	±1.5	267000	2.29
13	Strut Mounts(WG)	2 each	25	+1,-0	25	+1,-0	35	+1,-0	43750	0.37
14	Strut Mounts(BT)	2 each	15	+1,-0	25	+1,-0	50	+1,-0	37500	0.32
15	Probes	2 each	18	+1,-0	30	+1,-0	30	+1,-0	32400	0.28
16	WG Flange	1 each	25	+1.5,-0	145	±1.5	480	±1.5	1740000	14.91
17	RBT flange (RING)	1 each	25	+1.5,-0	290/230	±1.5	Ring	±1.5	612593	5.25
18	FBT Flange	1 each	20	+1.5,-0	330	±1.5	330	±1.5	2178000	18.67
	Flatness of Items 16, 17, and 18 better than ± 1 mm							TOTALS	2790592.5	23.92

2.1.2 Care should be taken in the rolling processes and subsequent handling so that no particles of foreign material are rolled or embedded in the surface. Prior to every fabrication step, the tools and the machine have to be cleaned.

2.1.3 The plates should not be mechanically polished after final rolling or machining.

2.1.4 The following defects are prohibited:

- Inclusions or clusters of foreign material of niobium oxides;
- Laminates, holes and cracks; and
- Etch defects or residues, scratches or other deposits like grease or fingerprints.

2.1.5 The plate should be shipped in a "surface etched" (chemically polished) condition.

2.2 Performance

2.2.1 Items 1 through 6 in Table 1:

2.2.1.1 Shall have surfaces free of scratches, blemishes, and inclusions.

2.2.1.2 Shall be made from ultra pure Niobium material with a Residual Resistivity Ratio, RRR = 250.

2.2.1.3 Items 1-5 shall be of deep drawing quality, grain size ASTM #5 or finer, local grain sizes ASTM #4 allowable, minimum 90 % recrystallized.

2.2.1.4 Item 6 shall be of **severe** deep drawing quality, grain size ASTM #5 or finer, minimum 90% recrystallized. **Uniform grain size is essential**. Sheets should be cross rolled during fabrication if vendor believes improved deep drawing quality will result.

2.2.2 Items 7 and 8 in Table1:

2.2.2.1 Shall be made from ultra pure Niobium material with an RRR = 250.

2.2.2.2 Shall have as small a grain size as possible, minimum 90 % recrystallized.

2.2.3 Item 9 in Table 1:

2.2.3.1 Shall have surfaces free of scratches, blemishes, and inclusions.

2.2.3.2 Shall be made from ultra pure Niobium material with an RRR = 400 preferred and an RRR = 280 guaranteed.

2.2.3.3 Shall be of deep drawing quality, grain size predominately ASTM #5 or finer, local grain sizes ASTM #4 allowable, minimum 90% recrystallized. Sheets should be cross rolled during fabrication if vendor believes improved deep drawing quality will result.

2.2.4 Items 10-12 in Table 1:

2.2.4.1 Shall be made of 99.85 % pure Niobium.

2.2.4.2 Shall have surfaces free of scratches, blemishes, and inclusions.

2.2.4.3 Shall be of deep drawing quality, grain size predominately ASTM #5 or finer, local grain sizes ASTM #4 allowable, minimum 90% recrystallized.

2.2.5 Items 13-18 in Table 1:

2.2.5.1 Shall be made of 99.85 % pure Niobium.

2.2.5.2 Shall have as small a grain size as possible, minimum of 90 % recrystallized.

2.2.6 Chemical composition of all ultra pure niobium shall conform to the criteria in Table 2.

Table 2: Allowable Niobium Impurities

Impurities	**Maximum Content**
Ta	≤ 0.1 % goal < 0.06 %
W	≤ 0.007 %
Ti	≤ 0.005 %
Fe	≤ 0.003 %
Si	≤ 0.003 %
Mo	≤ 0.005 %
Ni	≤ 0.003 %
H2	≤ 2 ppm typically
N2	≤ 10 ppm typically
O2	≤ 10 ppm typically
C	≤ 10 ppm typically

2.2.7 All material shall meet the mechanical properties listed below:

- Tensile strength > 110 N/mm^2
- Yield stress 0.2% > 50 N/mm^2 for all material with a thickness of 12 mm or less
- Yield stress 0.2% > 40 N/mm^2 for all material with a thickness of greater than 12 mm.
- Elongation AL30 > 30 %
- Vickers Hardness HV_{10} < 50 N/mm^2

2.2.8 Surface roughness of all sheet material shall be better than 0.8 microns (N6).

2.3 Safety and Environmental

2.3.1 Material shall be individually paper wrapped with acid free and alkaline free paper to prevent any surface damage.

2.3.2 The packing material used shall be sufficiently robust to ensure that the surface of the sheet is maintained in a good condition during transport.

2.4 Applicable Codes, Standards and Procedures

2.4.1 This specification covers unalloyed annealed Niobium plate and sheet. The plate and sheet material is to be produced in accordance with ASTM B393, " Standard Specification for Niobium and Niobium Alloy Strip, Sheet, Foil and Plate" with additional and overriding requirements as specified herein.

2.4.2 All tensile testing will be done in accordance with ASTM E 8, "Standard Test Methods for Tension Testing of Metallic Materials".

2.4.3 Grain size testing shall be done in accordance with ASTM E 112, "Standard Test Methods for Determining Average Grain Size".

2.4.4 Hardness testing shall be done in accordance with ASTM E92-82 e2, "Standard Test Method for Vickers Hardness of Metallic Materials" or ASTM E18-98, "Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials".

2.4.5 Dimensional test should be done in accordance with DIN 1751 or equivalent.

2.5 Quality Assurance

2.5.1 The vendor shall maintain and apply a quality assurance program compliant with ISO-9003 for the supply and inspection of all components.

2.5.2 The vendor shall provide evidence of its capability to perform the tasks outlined in this specification. The vendor should cite completion of past contracts of a similar nature and verify that it has access to the proper facilities to complete the manufacturing and testing of all the elements covered in this document.

2.6 Inspection and Testing

2.6.1 The CLS reserves the right to have access to the vendor's facility at any time during the fabrication and testing procedures. The CLS shall have the right to witness any manufacturing or testing procedures upon request.

2.6.2 The vendor shall provide evidence to verify that the supplied pieces meet or exceed the required performance characteristics. These test shall include, but not be limited to:

2.6.2.1 Chemical analysis. One analysis is required per ingot for metallic impurities.

2.6.2.2 RRR measurement. The RRR value is defined as the ratio between the electrical resistance at room temperature and the resistance at T = 4.2 K. For the measurements at 4.2 K the sample has to be placed in a sufficient magnetic field in order to suppress the superconducting state. Alternatively, the measurement can be performed just above the transition temperature of T = 9.2 K. RRR measurements are required of one sample per ingot.

2.6.2.3 Tensile strength test, Yield strength and Elongation tests are required of one sample per annealing lot.

2.6.2.4 Dimensional check. Thickness checks will be required at 4 points (corners).

2.6.2.5 Hardness Testing. Hardness testing shall be done at all corners of each sheet of the heating-lots.

2.6.2.6 Visual Inspections of the surface condition will be done on each sheet to locate any defects.

2.6.3 On two sheets on each annealing lot (minimum and maximum hardness) the following tests have to be performed in addition:

2.6.3.1 Chemical analysis. Analysis is required to determine the contents of H,O,C and N.

2.6.3.2 RRR measurements.

2.6.3.3 Micrographs with the evaluation of the grain size.

2.6.4 If the results of any properly preformed test show that the material does not meet the requirements as outlined in this specification, the vendor shall test two additional samples for every failed sample. Both of the subsequent tested samples must meet the requirements.

2.6.5 All measurement results shall be filed in hardcopy, on magnetic media, and archived at the vendor's location in duplicate.

2.6.6 One set of measurements in hardcopy and an electronic copy on magnetic media shall be sent to CLS after all major measurement tests.

2.7 Reliability and Maintainability

Not applicable.

2.8 Layout

Not applicable.

2.9 Other Requirements and Constraints

2.9.1 Each sheet has to be marked with a sheet number in one corner (max. total mark size: 2 cm^2).

2.9.2 The origin of each sheet to the ingot, forging-piece, head-lot etc. will be documented and will be made available on request to the CLS.