Brookhaven National Laboratory
Associated Universities, Inc.
STAR Collaboration

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Title: Specification for STAR Solenoid Magnet Poletip Trim Coils

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SPECIFICATION FOR STAR SOLENOID POLETIP TRIM COILS

1.0 General.

1.1 Summary.

This specification describes the Poletip Trim Coils to be used as part of a large solenoid magnet detector system. This detector system is known as the Solenoidal Tracker at RHIC (STAR) and will be installed in the Relativistic Heavy Ion Collider which is a particle accelerator being constructed at Brookhaven National Laboratory.

The magnet utilizes ten Main coil assemblies, two Space Trim coil assemblies and two Poletip Trim coil assemblies. Only the Poletip Trim coils are covered in this specification.

The Poletip Trim coils will each be installed into a 75 ton Poletip which will then be incorporated within a thousand ton steel yoke which will contain sensitive apparatus used in high energy and nuclear physics experiments. This detector system is a one-of-a-kind and must operate for long periods reliably. Consequently, this specification includes requirements for coil handling and manufacturing environment as well as detailing extensive electrical and mechanical tests during and following manufacture.

1.2 Scope.

This specification outlines the minimum requirements governing the design, materials, and testing of the Poletip Trim coils for the STAR detector. It should be read in conjunction with CSN #277, "Statement of Work for the Fabrication of STAR Solenoid Poletip Trim Coils."

2.0 Documents and Standards.

The following documents are an integral part of this specification:

2.1 Drawing List No. SDS-2 contains all drawing information relevant to the fabrication of these coils. This list is found in Appendix I.

2.2 Specification for STAR Solenoid Magnet Poletip Trim Coil Aluminum Conductor, CSN #133.

2.3 Published Standards:

ASTM B193 "Standard Test Method for Resistivity of Electrical Conductors"

ASTM B236 "Standard Specification for Aluminum Bar for Electrical Purposes (Bus Bars)"

ASTM B324 "Standard Specification for Aluminum Rectangular and Square Wire for Electrical Purposes"

All standards shall be the latest revision available at the time of the request for quotes.

3.0 Coil Parameters.

The STAR solenoid magnet contains two Poletip Trim Coils. Each coil contains six layers which are wound "three-in-hand" (tri-filar) fashion providing nine parallel water paths and one series electric current path.

The following coil parameters apply:

Number of water circuits/coil	9
Number of layers/coil	6
Number of turns/coil	118
Conductor height	0.875 inch
Conductor width	0.875 inch
Conductor hole diameter	0.484 inch
Conductor corner radius	0.13 inch
Electrical resistance of a water circuit @ 75°F	0.00746 ohm
Electrical resistance of a coil @ 75°F	0.0672 ohm
Length of conductor/water circuit	312 ft.
Length of conductor/coil	2808 ft.
Voltage across entire coil @ 75°F	97 volts
Design current through all turns	1441 amps
Water flow/circuit @ 75°F	5.3 gpm
Pressure drop @ 5.3 gpm	100 psi
Water flow through entire coil	47.7 gpm
Coil nominal inner radius	36.000 inch
Coil nominal outer radius	55.464 inch
Coil nominal width	5.693 inch
Coil weight	1.3 ton

4.0 Materials and Parts

4.1 Conductor.

The conductor shall be aluminum and in strict accordance with Specification CSN #133. It shall be electrical conductor grade type 1060, 1350 or 1370 and supplied in the F or T-0 temper condition with maximum resistivity at 68°F of 1.098 micro-ohm-in, which corresponds to 61.8% IACS. The cross section of the conductor shall be:

width 0.875 ± .004"
height 0.875 ± .004"
center hole 0.484" ± .005" diameter
corner radius 0.13" ± .010"

No welds for splicing the conductor are allowed; the conductor shall be extruded in lengths sufficient to wind the approximately 325 feet per water passage without a joint. All press stops shall be marked and reels labeled with this information.

The minimum diameter of a spool drum for the aluminum shall not be less than 36 inches. Only one length (piece) of conductor material, wound on a single layer, will be placed on each reel. Both ends of the conductor shall be exposed enough to allow pressure tests and flow tests while the conductor is still on the reels.

4.2 Connections.

4.2.1 Electrical.

The electrical connecting end bosses will be made of 6101 T-6 aluminum or approved equivalent as shown on drawings MAG203-C-1 and MAG204-C-4.

4.2.2 Water.

The water cooling connections will be made using stainless steel fittings screwed into the conductor bosses welded to the ends of each water passage. Details of the boss is shown on drawing MAG203-C-1 and MAG204-C-1.

4.3 Insulation.

4.3.1 Turn-to-Turn Insulation.

The combination of impregnating epoxy and Amino Silane treated glass fiber tape shall be used for the turn-to-turn insulation. The tape shall be 0.007 inches thick applied "half-lapped" to give a thickness of 0.014 inches and, after impregnating with the impregnating epoxy, the combination shall have a minimum rated room temperature dielectric strength of 250 volts per 0.001 inch (volts per mil).

4.3.2 Inter-layer Insulation.

Prior to impregnating with epoxy, an additional layer of insulation shall be present between each layer of pancake and between each pancake. This layer shall consist of DMD70555 (Arlon Adhesives: Films Division) insulating sheet 0.015 inches thick.

4.3.3 Overwrap Insulation

The overwrap insulation shall be the same material as the turn-to-turn insulation described in Section 4.3.1 except that 0.010 inch thick material shall be applied half-lapped five times to give a total thickness of 0.100 inches.

4.3.4 Impregnating Epoxy Mix

The impregnating mix and curing cycle for vacuum encapsulation of the coils shall be proposed by the coil fabricating vendor and approved by the buyer. As an example, an epoxy formulation and cure cycle that has been successfully used in the past is as follows:

#DER 332 (Dow Chemical) DGEBA Resin; 50 p.b.w.

#DER 736 (Dow Chemical) Polyglycol Flexible Resin; 50 p.b.w.
and cured with
NMA (Allied Chemical Co.) Nadic Methyl Anhydride; 90 p.b.w.

Acceleration of cure shall be through the use of 1.5 p.b.w. DMP-30 (Rohm & Haas) Tridimethyl Amino Methyl Phenol.

The epoxy curing cycle shall take place at atmospheric pressure as follows:

180°F ± 5°F for 6 hours
260°F ± 5°F for 12 hours
Controlled cooldown to 140°F @ 20-25°F per hour.

During the curing cycle, all temperatures will be recorded and this record shall be included with the coil traveler.

4.3.5 Coil Leads

Each coil lead or "tail" shall have a portion insulated with “Raychem” BPTM-100/40 AU and BPTM-50/20 Au heat shrunk insulation as shown on drawings MAG200-E-6 and MAG200-E-7. The heatshrink insulation will extend to and join with the tape insulation applied to the leads as they emerge from the coil package.

4.3.6 Filler Material

The filler pieces used on each pancake inside surface for the two-in-hand and layer-to-layer transitions shall be cast or machined in a fashion to insure uniformity of placement when winding on the turns. Additionally, all gaps between the conductor material and the outside of the coil package shall be filled with an approved epoxy impregnated glass fiber material.

4.4 Structural Epoxy

The flange shown in drawing MAG206-E-1 shall be bonded to the coil assembly using structural epoxy as shown in drawing MAG200-E-1. The epoxy shall cover as large an area as possible at the coil/flange interface. The epoxy, chosen by the Seller shall be compatible with both items being bonded and shall exceed the following strength requirements:

Shear strength = 1500 psi
Tensile strength = 500 psi

See CSN # 277 paragraph 11.0 for mandatory structural epoxy testing requirements.

5.0 Tests and Inspection.

5.1 Aluminum Conductor.

5.1.1 Before any aluminum conductor is wound into a coil it shall be tested in accordance with Specification CSN #133.

5.1.2 In the event that the tests described in Section 5.1.1 are performed at the conductor manufacturing location, an inspection will be performed at the winding facility to assure that no decrease in the conductor quality occurred during shipping.

5.2 Insulating Materials.

All insulating materials shall be inspected to determine their "shelf life" and to assure that they are used prior to the expiration of the shelf life. UNDER NO CIRCUMSTANCES shall material be used beyond its shelf life period.

5.3 Fluid Tests.

Following coil winding and all welding processes, the following fluid tests will be performed:

5.3.1 Pressure Test.

The ends of each water path will be sealed and the bore pressurized to a minimum of 375 psig with clean water. The water path shall be isolated from the pressure source and the pressure in the bore monitored for one hour. Any loss of pressure other than due to

temperature change effects shall be deemed a test failure. The result of this test shall be recorded as outlined in Section 5.8.

5.3.2 Flow Test.

Each water path shall be tested to confirm a flow at least 5.1 gallons per minute of 75°F water with a pressure drop between the inlet and outlet of no more than 100 psig. The result of this test shall be recorded as outlined in Section 5.8.

Immediately following the fluid tests, the bore will be blown dry and will be sealed with suitable caps.

5.4 Electrical Tests.

5.4.1 Turn-To-Turn Tests.

Prior to and following epoxy impregnation, adjoining water paths shall be tested by applying a minimum of 200 volts DC between them and measuring leakage current. A leakage current greater than 25 microamps is a test failure. In a similar manner, a minimum of 400 volts DC shall be applied between layers prior to and following impregnation and the leakage current measured. A leakage current greater than 25 microamps is a test failure. These tests will be accomplished prior to electrically joining all water paths and pancakes. The whole coil turn-to-turn test shall be proposed by the vendor in his fabrication procedure and approved by the Buyer. Results of the final turn-to-turn test shall be recorded as outlined in Section 5.8. Results of tests performed prior to the final test shall be recorded on the coil traveler.

5.4.2 Ground Test.

The ground test shall be performed by wrapping the coil tightly in rags soaked in an electrically conducting liquid. Ordinary tap water is probably adequate. Ground tests shall be performed by applying at least 4000 volts DC between the conductors and the wet rags. A leakage current greater than 50 microamps is a test failure. Results of the ground test shall be recorded as outlined in Section 5.8.

5.5 Electrical Conductivity Tests.

The electrical conductivity of each conductor shall be determined by measuring resistance end-to-end:

- After completing the winding of the coil, the resistance of each water circuit shall be measured. A resistance at 75°F or equivalent of more than 0.00772 ohms is a test failure. The results of the conductivity test shall be recorded as outlined in Section 5.8.

- Upon completion of coil assembly, the resistance of the coil shall be measured end-to-end. A resistance of more than 0.0695 ohms at 75°F or equivalent is a test failure. The results of the conductivity test shall be recorded as outlined in Section 5.8.

5.6 Dimensional Checks.

All dimensional checks and measurements shall be made with the items being measured and the instrumentation at 75°F else temperature effects shall be considered.

The Seller shall inspect each coil after the final epoxy cure for compliance with the appropriate drawing dimensional tolerances. Non-compliance with drawing dimensional requirements is a test failure and grounds for coil rejection.

The results of the dimensional checks shall be summarized as outlined in Section 5.8. Additionally, the Seller shall mark up a copy of the appropriate drawing for each coil assembly with the "as built" dimensions recorded. The coil serial number must be on these drawings.

5.7 Obstruction Test.

Following all fabricating procedures, the bore of each water path shall be tested to be free of obstructions by passing a ball of 0.297 ± 0.005 inch minimum diameter through its entire length. The results of this test shall be recorded as outlined in Section 5.8.

5.8 Test Records.

An inspection report shall be prepared for each coil assembly. This report shall record all test results, the name of the person performing the test, test date and test outcome. As a minimum, the report shall include:

Coil Name
Coil Assembly Drawing Number and Revision Letter
Coil Serial Number
Results of Conductor In-coming Inspection
Serial Numbers of Conductor Lengths used in this coil
Results of Pressure Test
Pressure drop and flow rate data for each water path. Also test water temperature
Turn-to-Turn Test
Ground Test Data including Test Voltage and Leakage Current
Electrical Conductance and resistance of each water path
Electrical Conductance and resistance of coil
Results of Dimensional Check
Results of Obstruction Test

6.0 Markings.

Prior to shipment, the Seller shall mark and identify each coil assembly by drawing number and revision letter, Seller's name, and a unique serial number generated by the Seller. This information shall be painted with white epoxy paint in the location as specified in the drawings. No other permanent markings may be applied without the approval of the Buyer.

APPENDIX I

DRAWING LIST NO. SDS-2

Title	Number
Winding Assembly	MAG200-E-1
“	MAG200-E-2
“	MAG200-E-3
“	MAG200-E-4
“	MAG200-E-5
“	MAG200-E-6
“	MAG200-E-7
Aluminum Coil Conductor	MAG201-B-1
Jumper End Boss	MAG203-C-1
Power End Boss	MAG204-C-1
Lifting Bracket	MAG205-D-1
Flange	MAG206-E-1
Pole Tip - East (for reference)	MAG344-E-1
Pole Tip - West (for reference)	MAG345-E-1