Relativistic Heavy Ion Collider
Magnet Division Procedure

Proc. No.: RHIC-MAG-M-7142

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Class: Ancillary Specifications
Title: RHIC 8cm Aperture Dipole/Quadrupole Cable Test Methods

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REVISION RECORD

Rev. No.	Date	Page	Subject	Approved	QA
A	7/20/89	1,3,4,8,9, 10,12,17,18	Data Recording	On File	
B	1/3/90	1	Ref. To Wire & Cable Spec.	On File	
C	2/7/90	2,9,10,17	3.1.1 - Revised Tooling	On File	
D	4/26/90	2,4,8,9,10,1 8	Ref. To wire & cable spec.; 10x mag.; etch	On File	
		3,4,6,7	unbent samples. Consolidation of Data	On File	
		8,9,10,14,15	Recording		
E	6/26/91	-	Production RFQ Release.		On File
F	10/9/92	4	Add observation of "Blosoming".		
			Referenced in Spec. RHIC-MAG-M-4141, ECN MG00215	On File	On File

1. Scope:

This procedure establishes the test requirements for RHIC Dipole Magnet Cable Thickness (Bare-Mean), width, residual twist, keystone, and sharp bend.

1.1 Applicable - The test methods specified in Appendix A shall be used whenever such tests are required for confirmation of cable conformance.

2. Applicable Documents:

The following documents of the issue in effect on the date of invitation to quote, form a part of this procedure to the extent specified herein.

RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

3. Requirements:

3.1 Test method procedures and requirements for the following tests are included in Appendix A.

Test Method No. 1 - Bare Cable Thickness Measurement (Mean)

Test Method No. 2 - Cable Width

Test Method No. 3 - Residual Twist

Test Method No. 4 - Cable Keystone Angle

Test Method No. 5 - Cable Sharp Bend Test

3.2 Test Data - Quantitative data resulting from the performance of Appendix A tests shall be entered in appropriate format in the RHIC Strand & Cable Magnet Data Recording System.

4. Quality Assurance Provisions:

The Quality Assurance Provisions of this procedure require compliance with the procedures specified in Appendix A.

5. Preparation for Delivery:

N/A

APPENDIX A - Test Method No. 1

Bare Cable Thickness Measurement (Mean)

1. Purpose:

This procedure establishes a standardized procedure for testing bare RHIC dipole magnet cable using a portable compression test fixture.

2. Applicable Documents:

RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

2.1 Materials Required:

2.1.1 Mylar tape, approx. 1 in.-wide x 1 mil thick (not critical) or equivalent.

3. Requirements:

3.1 Test Equipment:

3.1.1	Measurement Fixture (Supplied by BNL)	BNL Dwgs.	25-606.01-4 25-978.01-3

3.1.2 A bench-mounted shear (or equivalent) for making a clean cut on the cable without deforming it excessively.

3.2 Procedure:

Note: Test Conditions

1. Temperature unless otherwise specified: 75 ± 5^{o}F.

2. Relative Humidity: 65% RH max.

3.2.1 Mean Single Layer Thickness of the Bare Conductor @ 5 Kpsi

3.2.1.1 Identifying the Edges:

All insulation (Fiberglass and Kapton) are stripped from the cable. The edges of the (4 ft. +) sample of bare cable are identified by painting the thick edge (which automatically defines both, the painted and the unpainted) along its entire length (Fig. 1), using a felt tip marking pen.

3.2.1.2 Cutting the Strips:

Mylar tape or equivalent, is wrapped at 3-1/4" to 5" intervals for a minimum of 10 strips. The cable is then cut at these intervals, such that at each cut the Mylar tape is cut approximately in half with each strip retaining approximately 1/2 of the tape at each end. This helps to keep the cable from unraveling. This is depicted in Fig. 2.

3.2.1.3 Zeroing the Measurement Fixture:

The standard block is inserted into the appropriate fixture (boat) which in turn is mounted in the measuring fixture. Be sure to lift both spindle levers during boat insertion. Check back of fixture for boat contact with stop. Pressure is applied to the standard until pressure gauge pointer points to "5" (1850 psi fluid pressure). This load applies a pressure on the standard of 5 Kpsi. Pump to "5" twice. Hold pressure on second pump-up and turn on the Fowler Gauges. Press the "clear" button to set zero. Check for "inches" (in.) indicator in corner of gauge to assure that all measurements will be in the proper units. Release the pressure and remove the boat while holding down gauges' spindle levers. If the gauges are running on their batteries you have four (4) minutes to complete the measurements as the gauges automatically shut down to conserve battery life. If the gauges are charging their batteries (running off house current) there is no time limit and no automatic shut down.

3.2.1.4 Stacking:

The 10 cut strips are then stacked in the appropriate fixture (boat), so that the painted edges alternate. This insures that the cable stack is of rectangular cross section. The individual cable strips should be approximately centered lengthwise in the boat.

3.2.1.5 Measuring Cable Thickness at 5 Kpsi:

A) Cycle pressure from approx. 1K to 10 Kpsi two (2) times.

B) On 3rd cycle record indicator readings at 5 Kpsi.

C) Calculate cable thickness using equation shown below and enter readings on the traveler (Form 1).

3.2.1.6 Calculation of Bare Cable Single Layer Thickness at 5 Kpsi:

Mean thickness of a single layer of bare cable is calculated from the deflections recorded in cycle 3 of para. 3.2.1.5 according to the following formula.

A)

$$THK = \frac{STD + \frac{L + R}{2}}{10} \; Inches$$

B) Definitions:

STD = Standard block dimensions stamped on block

THK = Mean thickness of single layer of bare cable

L = Left indicator reading

R = Right indicator reading

3.2.1.7 Microscopic Examination:

Measure, tape and cut two (2) 10" - 12" long cable samples. The tape prevents sample ends from unraveling. Examine both samples under a microscope to check for surface damage and/or chips. Enter observations on the traveler (Form 1).

3.2.1.8 Acid Etch Samples:

Pour Nitric Acid into water to create a 50% mixture acid bath. Immerse both samples from 3.2.1.7 in acid. When etching the samples, they must be in a straight configuration, unbent and stress-free. After the copper matrix has been etched away, place the samples in a water and baking soda bath to neutralize the acidic residue on the samples. Examine the samples under a microscope for filament damage. Strands showing severe filament breakage (>5%) under 10x magnification indicate unacceptable cable. Enter observations on the traveler (Form 1).

Observe the etched wires in the cable sample to determine that no "blossoming" of the filaments has occurred. "Blossoming" is a condition whereby the filaments separate from each other. It is normally a simple indicator that the wire twist is incorrect.

CAUTION

Etched superconductor (NbTi) has been known to burst into flames and burn rapidly. Avoid sparks, heat, and open flame. Package samples individually in fire retardant/proof containers for storage or disposal. Use standard disposal methods for flammable materials.

USE EXTREME CAUTION when handling etched superconductor!

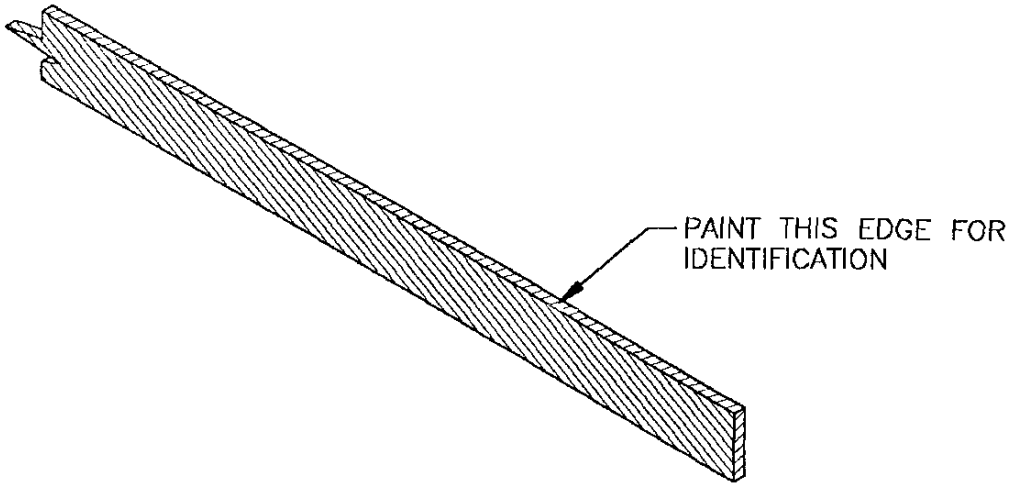


FIGURE 1–IDENTIFYING THE CABLE EDGE

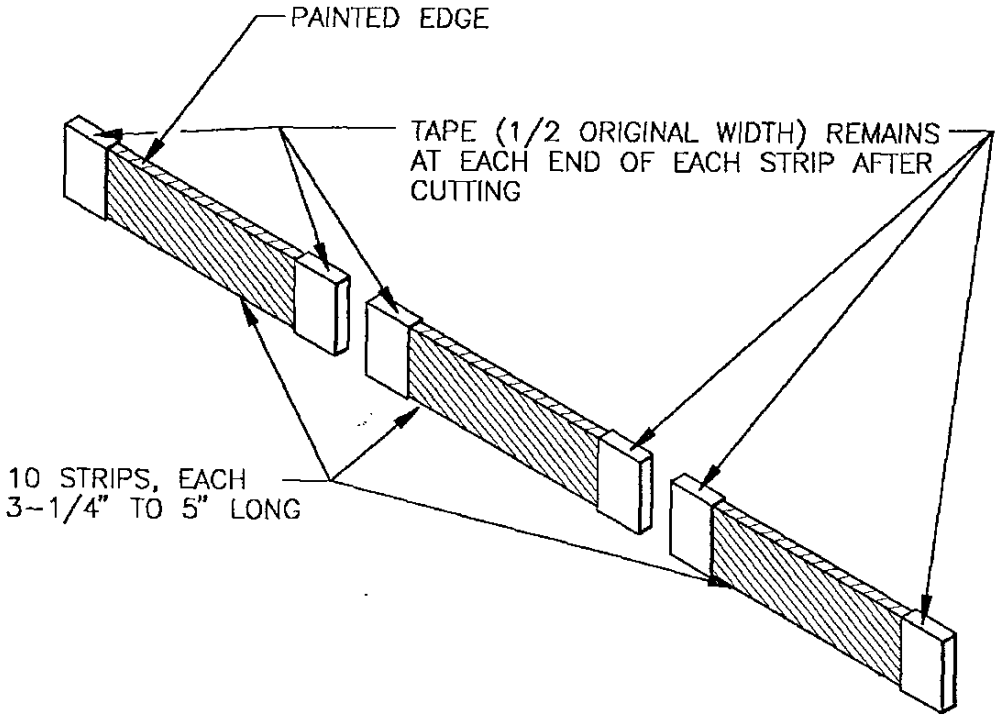


FIGURE 2– CUTTING THE STRIPS

APPENDIX A - Test Method No. 2

Bare Cable Width Measurement

1. Purpose:

This procedure establishes a standardized procedure for measuring bare RHIC dipole magnet cable width. Measurements are made with the cable under tension mounted in the cable twist measurement fixture.

2. Applicable Documents:

RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

2.1 Materials Required:

2.1.1 Cut a 4 ft. length of S.C. cable to be measured.

3. Requirements:

3.1 Test Equipment:

3.1.1 Cable Twist Measurement Fixture - BNL Dwg. No. 25-715.01-4.

3.1.2 Cable Width Measurement Fixture - BNL Dwg. No. 25-716.01-4.

3.2 Procedure:

3.2.1 Lay cable on table and mark at two inches (2") thirty eight (38") from one end of sample.

3.2.2 Clamp cable in twist measurement fixture such that two inch (2") marked end is secured at the weighted end of fixture. Bend upper end of cable over dowel and clamp in place. Sharp bend to occur two to three inches beyond the thirty eight inch (38") mark. This will allow a three foot (3') unrestrained test length.

3.2.3 Zero the width measurement fixture and mount on the track behind the cable.

3.2.4 Release support for 40 lb. weight and engage "stop" to prevent cable from untwisting.

3.2.5 Move width measuring device to the six (6) preselected measuring points along the cable.

3.2.6 Measure and record the cable width at these six (6) points. Compute and record the average width. Enter average width of the cable on the traveler (Form 1).

APPENDIX A - Test Method No. 3

Cable Residual Twist Measurement

1. Purpose:

This procedure establishes a standardized procedure for testing RHIC dipole magnet cable to determine the residual twist remaining after cabling.

2. Applicable Documents:

RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

2.1 Materials Required:

2.1.1 Cut a 4 ft. length of S.C. cable to be tested.

3. Requirements:

3.1 Test Equipment:

3.1.1 Cable Twist Measurement Fixture - BNL Dwg. No. 25-715.01-4.

3.2 Procedures:

3.2.1 Lay cable on table and mark at two inches (2") thirty eight (38") from one end of sample.

3.2.2 Clamp cable in twist measurement fixture such that two inch (2") marked end is secured at the weighted end of fixture. Bend upper end of cable over dowel and clamp in place. Sharp bend to occur two to three inches beyond the thirty eight inch (38") mark. This will allow a three foot (3') unrestrained test length.

3.2.3 Verify that angular measuring device is set to zero degrees.

3.2.4 Release support for 40 lb. weight and allow cable to untwist.

3.2.5 Record angular measurement when cable comes to rest. Enter the angular measurement, with direction of rotation, onto the traveler (Form 1).

APPENDIX A - Test Method No. 4

Cable Keystone Angle Measurement

1. Purpose:

This procedure establishes a standardized procedure for laboratory measurements of the keystone angle of RHIC dipole magnet cable.

2. Applicable Documents:

2.1 RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

2.2 Cable Keystone measurement fixture calibration procedure (SOP #002).

2.3 Cable Keystone measurement data sheet (Fig. 2).

2.4 Traveler - Keystone Angle - Form 1.

3. Requirements:

3.1 Test Equipment:

3.1.1 1" micrometer, 0.0001" resolution.

3.1.2 Cable measurement fixture frame/control console assembly (incl. pneumatic cylinders, LVDT resolution to 0.00001"), BNL design and manufacture.

3.1.3 Cable measurement fixture assembly, BNL Dwg. 25-00.107-2.

3.1.4 Cable insert, BNL Dwg. 25-00.165-3.

3.1.5 Cable standard, BNL Dwg. 25-00.163-3.

3.2 Materials Required:

3.2.1 Cleaning solvent (degreaser, not critical).

3.2.2 Mylar tape, 1 wide x 0.001" thick (not critical) or equivalent.

3.3 Procedure:

NOTE: Cable keystone angle measurements are to be performed on all cable samples.

3.3.1 Cable Specimen Preparation:

3.3.1.1 Strip insulation from cable, degrease (if necessary), and insure minimum length of 16".

3.3.1.2 Mark 3" center section of cable both sides to insure all measurements are performed at same location of specimen.

3.3.1.3 Mark thick edge of cable and index one face of cable (using felt tip marker) to insure proper specimen orientation in cable insert (see Fig. 1).

3.3.1.4 Mark cable with spool number and other applicable information (bare, wrap, coil, etc.).

3.3.2 Zeroing the Measurement Fixture:

Insure that the fixture assembly upper and lower plates are clean. Clean appropriate cable insert and standard, and place in fixture slot with "FWD" facing front (see Fig. 3). Cycle from minor to major compressive loads four (4) times. At last cycle and while at major compressive load (equivalent to 2.0 Kpsi on cable) adjust LVDT outputs to zero $\pm$ 0.01 mil. Release load and remove standard.

3.3.3 Measurement of Cable Keystone Angle at 2.0 Kpsi:

3.3.3.1 Place the cable specimen into the cable insert with the cable thick edge (as previously marked) to the left and the face with the index mark up (see Fig. 1). Adjust lengthwise so that the 3" center section of the specimen is centered in the insert, and secure the cable ends in the tension clamps. Insure that the cable specimen is properly seated in the cable insert slot. Apply a 40 lb. tensile load to the specimen.

3.3.3.2 Cycle from minor to major compressive loads six (6) times. At each major load record the LVDT outputs on the data sheet. (Fig. 2). At the completion of the 6th cycle, release the compressive load.

3.3.3.3 Remove compressive and tensile loads, and remove specimen from fixture. Reinstall specimen in fixture as in Para. 5.3.1 except the face with the index mark down (see Fig. 1). Repeat Para. 5.3.3.

3.3.3.4 Remove the specimen and place the cable standard into the cable insert as in Para. 5.2. Verify that the LVDT outputs are within zero $\pm$ 0.20 mil.

3.3.4 Keystone Angle Calculation:

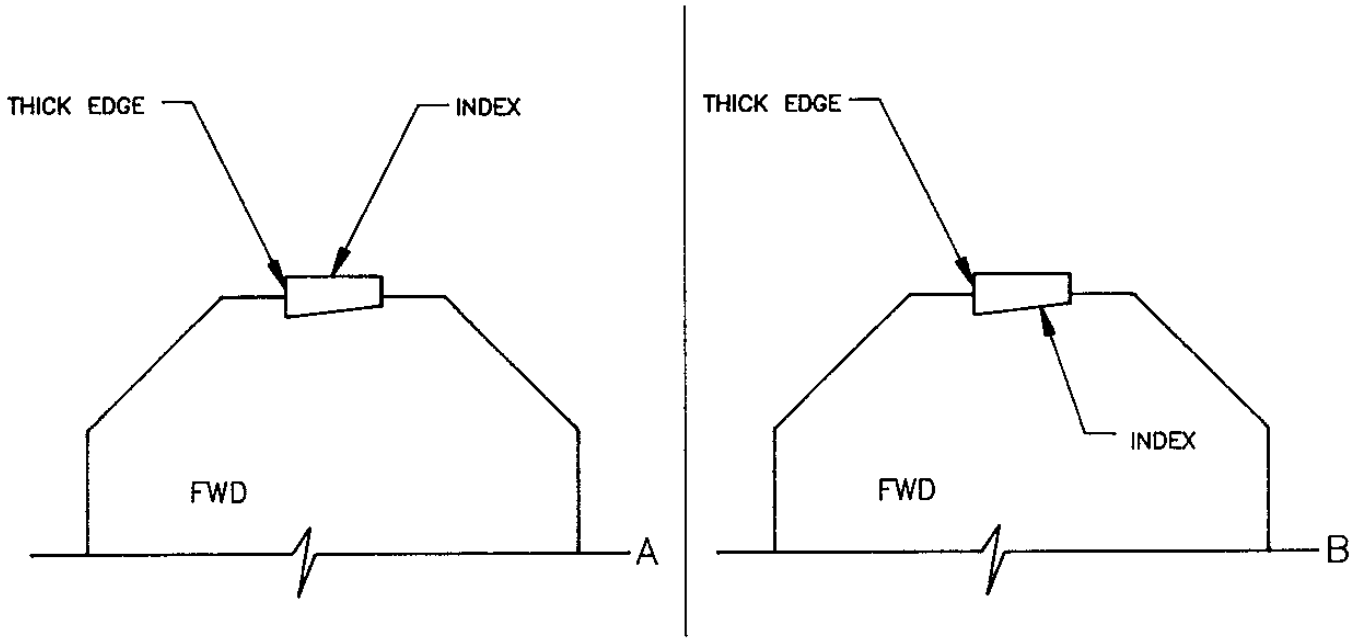
3.3.4.1 The data from Cycle #6 major compressive loading (12 measurements total) are used for the keystone angle calculation. All calculations are performed to 0.001 degree. Applicable formula is:

$$Angle = STD.angle + \arcsin \frac{C(R - L)}{3250}$$

NOTE: Value "C" in above formula is determined by LVDT sensitivity (gain) and is verified and/or adjusted by periodic fixture calibration.

3.3.4.2 The mean value and standard deviation are calculated for the two (2) cable measurements at tension = 40 lbs. recorded on the data sheet.

3.3.4.3 The mean value obtained from the above calculations is rounded to the nearest 0.01 degree and transcribed to the traveler (Form 1). Out-of-procedure values are so denoted. Copies of this summary sheet are then forwarded to the designated parties.



(FIGURE 1).

CABLE/INSERT ORIENTATION

NOTE: ONE COMPLETE CYCLE OF MEASURMENTS TO BE PERFORMED FOR EACH OF 2 ORIENTATIONS SHOWN.

CABLE KEYSTONE ANGLE DATA SHEET

DATE REC'D: __/__/__ SAMPLE TYPE:___ BARE, ___WRAPPED

NOMINAL ANGLE: _____ 1.20°

REMARKS: _____

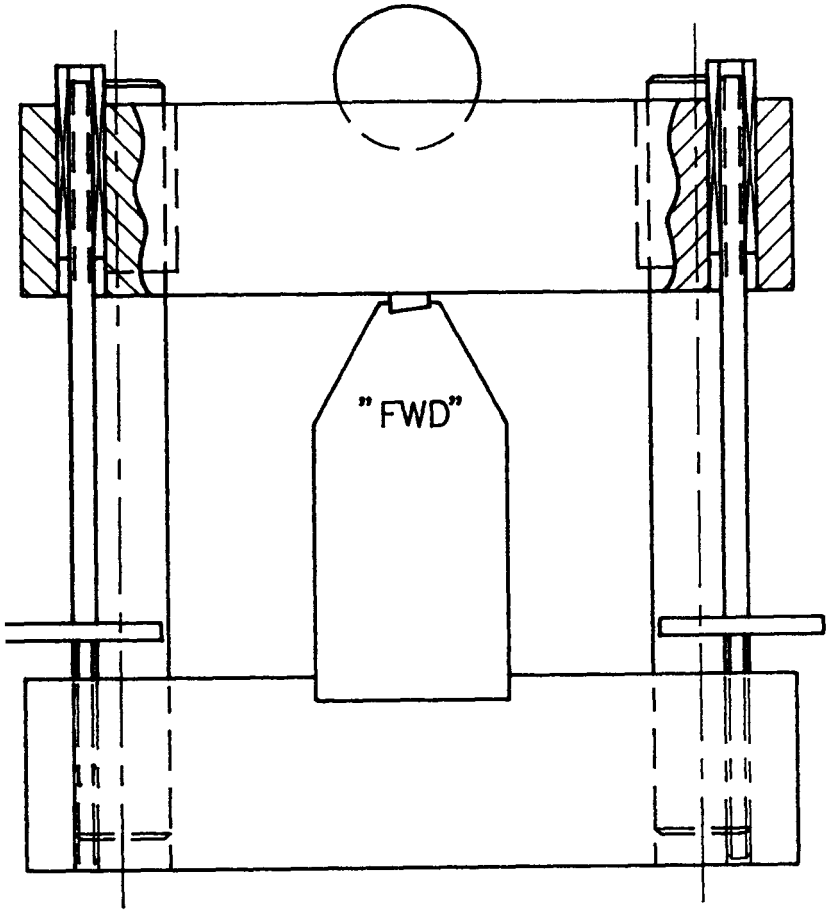
_____

CABLE #._____ DATE MEAS__/__/__

C	LEFT	RIGHT	FWD	REMARKS
1	.	.		
2	.	.		
3	.	.		
4	.	.		
5	.	.		
6	.	.		
1	.	.		
2	.	.		
3	.	.		
4	.	.		
5	.	.		
6	.	.		

ZERO CHECK . .

(FIGURE 2).



FRONT VIEW

SECTION ALONG LVDT CENTERLINE
OF FIXTURE ASS'Y BNL#25-00.107-2

(FIGURE 3).

CABLE/STANDARD INSERTION
INTO MEASURMENT FIXTURE

APPENDIX A - Test Method No. 5

Bare Cable Sharp Bend Test

1. Purpose:

This procedure establishes a standardized procedure for measuring bare RHIC dipole magnet cable's ability to sustain a sharp bend. Measurements are made with the cable under tension mounted in the cable twist measurement fixture.

2. Applicable Documents:

RHIC-MAG-M-4141 - Nb-Ti Superconductor Wire and Cable for RHIC Dipole and Quadrupole Magnets With 8cm Aperture.

2.1 Materials Required:

2.1.1 Cut a 4 ft. length of S.C. cable to be measured.

3. Requirements:

3.1 Test Equipment:

3.1.1 Cable Twist Measurement Fixture - BNL Dwg. No. 25-715.01-4.

3.2 Procedure:

3.2.1 Lay cable on table and mark at two inches (2") thirty eight (38") from one end of sample.

3.2.2 Clamp cable in twist measurement fixture such that two inch (2") marked end is secured at the weighted end of fixture. Bend upper end of cable over dowel and clamp in place. Sharp bend to occur two to three inches beyond the thirty eight inch (38") mark. This will allow a three foot (3') unrestrained test length.

3.2.3 Release support for 40 lb. weight and engage "stop" to prevent cable from untwisting.

3.2.4 Examine the cable's sharp bend to be sure that the cable is flush against the dowel and under tension.

3.2.5 Remove the bent cable from the test fixture and examine for cracks under 10x magnification. Straighten bend and examine for cracks under 10x. Enter the applicable "Pass" or "Fail" on the traveler (Form 1).

3.2.6 Acid Etch:

Pour Nitric Acid into water to create a 50% mixture acid bath. Wrap tape around the cable close to the bend and cut the cable through the tape. (Tape prevents the cable from unraveling.) Straighten the bend in the cable and immerse it in acid. (When etching the sample it must be in a straight configuration, unbent and stress-free.) After the copper matrix has been etched away, place the samples in a water and baking soda bath to neutralize the acidic residue on the sample. Examine the sample under 10x magnification for filament damage. Enter the appropriate "Pass" or "Fail" on the traveler (Form 1).

CAUTION
Etched superconductor (NbTi) has been known to burst into flames and burn rapidly. Avoid sparks, heat, and open flame. Package samples individually in fire retardant/proof containers for storage or disposal. Use standard disposal methods for flammable materials.
USE EXTREME CAUTION when handling etched superconductor!

TRAVELER

INSPECTION FOR: Mean Thickness, Microscope/Acid Etch, Mean Width, Residual Twist, Keystone Angle and Sharp Bend.

_____ ___ (Note: only one sample per traveler.)

Cable Number Seg.

DATA BASE

MEAS DATE	TM-1 MEAN THICKNESS	TM-1 ROOM TEMP.(F)	TM-1 MICROSCOPE pass	TM-1 MICROSCOPE fail	TM-1 ACID ETCH pass	TM-1 ACID ETCH fail	REMARKS

DATA BASE

MEAS DATE	TM-2 MEAN WIDTH	TM-3 RESIDUAL TWIST	TM-4 KEYSTONE (T=40 LBS)	TM-5 SHARP - BEND MICROSCOPE pass	TM-5 MICROSCOPE fail	TM-5 ACID ETCH pass	TM-5 ACID ETCH fail	REMARKS

FORM 1