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Title: Cable Sample Test Method

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- Section Head, Magnet Design & Test: Signature on File
- Q. A. Approval: Signature on File
- ES&H Review: Signature on File

REVISION RECORD

Rev. No.	Date	Page	Subject	Approval
A	7/30/07		Initial Release	

1 Scope

This procedure describes the method to be used to prepare and test samples of Rutherford cables in the Cable Test Facility at Bldg 902 in the Magnet Division.

2 Applicable Documents

Magnetic Division Note No. 599-32 *(AM-MD-300)* Section 5

3 Requirements

3.1 Material /Equipment

30 kA power supply for sample (Rapid Electric, with BNL computer control circuitry)
5 KA power supply for magnet (BNL computer control-circuitry)
Fluke 8520 peak reading DVM
Fluke 8520A DVM (Hazemeyer output)
Hazemeyer 10 kA model DCCT
Hazemeyer 15 kA model DCCT- 2 required
HP 1 A Power Supply 6632A
HP 3497A DVM/Scanner
HP34401A DVM's - 2 required
HP3458A DVM's - 3 required
HP3497 data scanner
Nicolet digital oscilloscope, Model 4094
Omega DP460T thermocouple E units
PC
Pulsed power supply for sample- quench heater. 0-100 ms, 0-50 V, BNL built.

3.2 Safety Precautions

3.2.1 Specific steps of this procedure contain Electrical & Mechanical Assembly operations that impact the environment. Prior to performing these steps, personnel shall complete the applicable facility specific environmental training.

3.2.2 Electrical personnel protection is provided by a Kirk-Lock system in the test areas. Ensure system has been verified within the past 6 months prior to use.

3.2.3 Only personnel trained for incidental rigging and holding a current Safety Awareness Certificate can operate the crane. Hard Hats must be worn by all personnel in the area during crane operations. Safety shoes are recommended to be worn.

3.2.4 Eye protection is required to be worn during soldering operations.

3.3 Procedure

3.3.1 Receiving, Inspection and Entry into Database (Cable Flow)

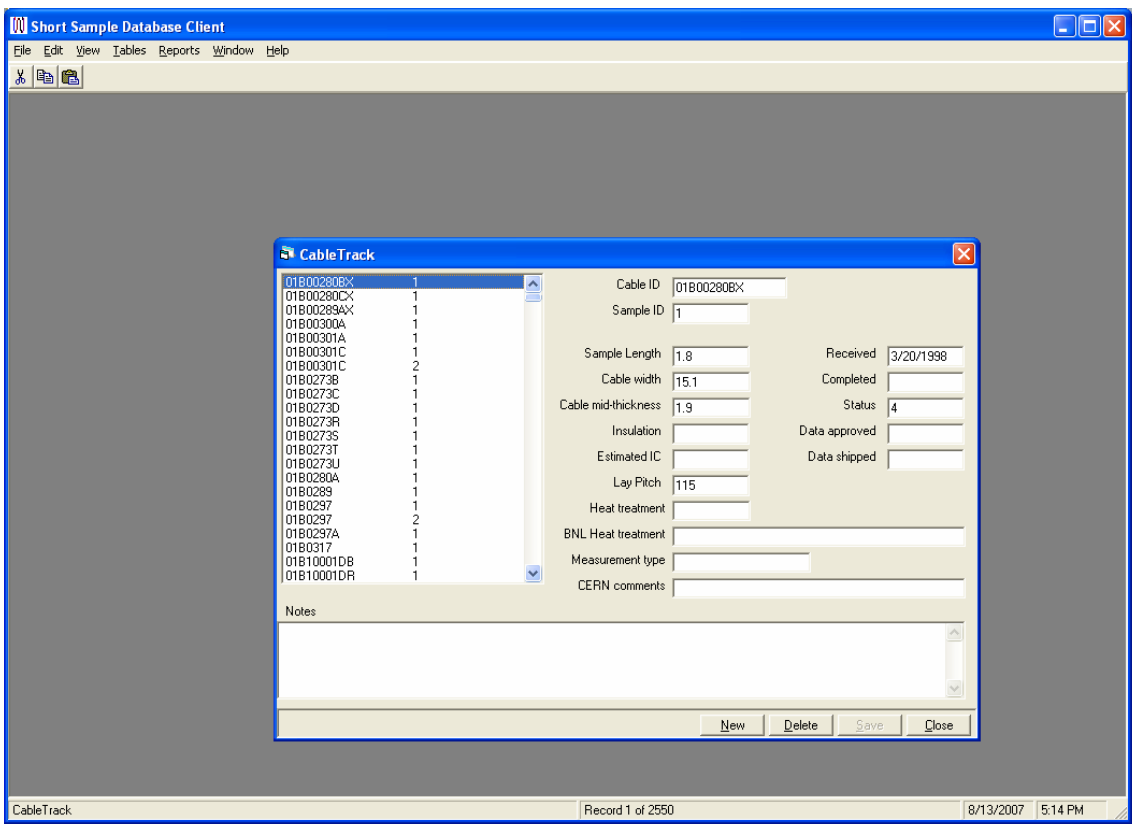
When new samples arrive at BNL and are delivered by BNL's Shipping and Receiving division, a member of the Superconducting Magnet Division runs the Short Sample Database Client Program.

3.3.1.1 Entering New Samples into the CableTrack Table

3.3.1.1.1 Before a new sample can be used in a testing Assembly, it needs to be entered into the CableTrack table of the SQL Server Short Sample database.

3.3.1.1.2 The user must enter a Sample ID, since an individual record is entered into the CableTrack table for every cable sample with the actual date the cables were received at BNL. This is done by clicking on the "New" button and filling out the information for the cable and then clicking on the "Save" button.

3.3.1.1.3 Once the record is added, the value of the Status field is set to zero to indicate the sample's current status. This status field is updated as the sample proceeds through the steps of being incorporated into a testing assembly, being tested, etc.



3.3.1.2 Creating Entries in the CableAssembly Table

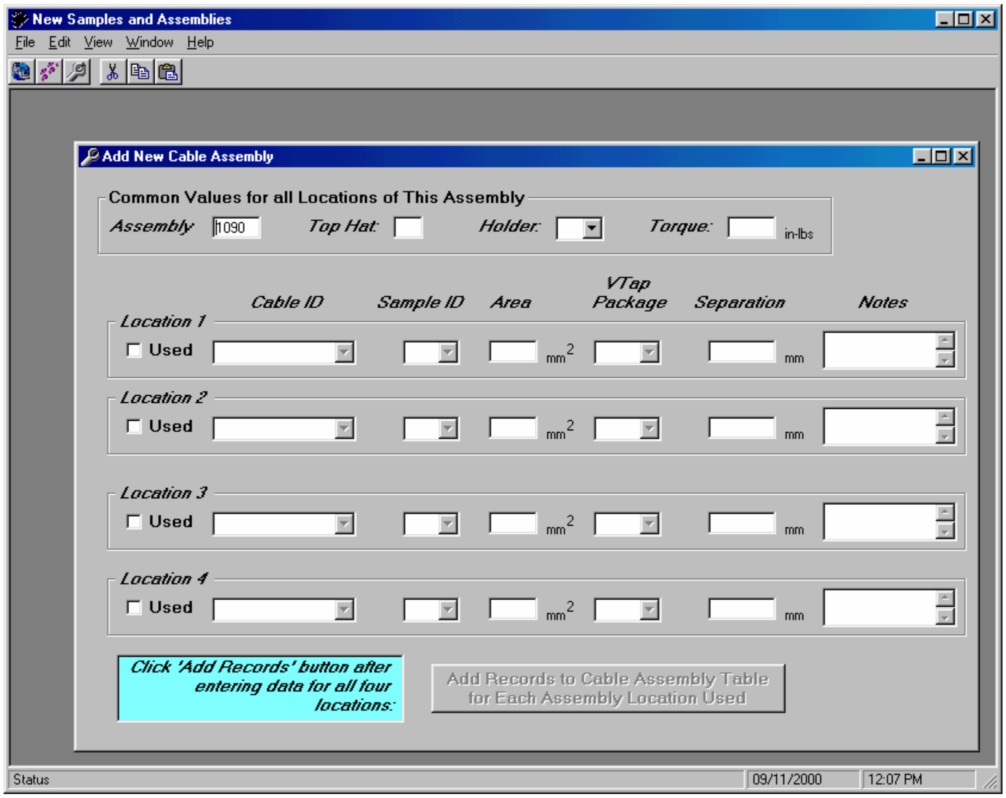
To create a new assembly of samples for test, a user runs the "New Samples" application program.

3.3.1.2.1 When the user clicks on the "Wrench" icon, a form appears for entering records into the CableAssembly table. The Assembly number is automatically filled in based on the next available sequential number, but it may be modified by the user.

3.3.1.2.2 An Assembly may accommodate up to four cable samples. The boxes with the down arrows allow only selections from a list of possibilities, so the database tables are not corrupted or become inconsistent. When the Cable ID is selected, the Area information is automatically filled in, but may be modified. The program also verifies that the same cable-sample ID does not appear at more than one location in the same Assembly.

3.3.1.2.3 When the form has been completed and the "Add . . ." button clicked, a new record is added to the CableAssembly table for each location used and the Status field of the CableTrack table is updated for each cable sample.

3.3.1.2.4 The Short Sample database now contains all the information necessary to begin warm measurements and further testing.



3.3.2 Pre-Assembly of Cable Samples

3.3.2.1 Check cable ID's and record on Cable Joint Fabrication worksheet.

3.3.2.2 <u>Visual inspection</u>: Note any burrs, chips, dirt, oil and/or grease, cross-over wires, cut or damaged strands.

3.3.2.3 <u>Mechanical measurements</u>: Record hand micrometer measurements of thin edge, thick edge, and width at three separate locations.

3.3.2.4 Mark the thin edge of the sample with an indelible marker along the entire length.

3.3.2.5 Label sample identification with a indelible marker on the face and on a masking tape flag about 10 inches from the lead end. (This will serve as identification when the sample is clamped)

3.3.3 Solder Joint Fabrication

3.3.3.1 Note the type of joint being made for the pair of cable samples, either a Type-B or a Type-C joint

3.3.3.2 Prepare solder fixture by cleaning with a wire brush, then brush paste flux onto the bottom surface (groove) of the fixture.

3.3.3.3 Lay two pieces of “StayBrite”(Sn with 4%Ag)solder ribbon, side by side into the groove.

3.3.3.4 Brush each surface of the sample with paste flux. Observing the marked edge, lay the sample into the groove.

3.3.3.5 Alternately continue with two solder ribbons then the next sample, observing the marked edge of the sample now opposite the first, then place two additional ribbons.

3.3.3.6 Install the aluminum separator; repeat the procedure starting with the third sample’s marked edge in the same direction as the second’s. Install the fixture top, secure with bolts and hand-tighten. Support the samples and clamp lead-end of samples to prevent the spreading of the wires at the end of the cable.

WARNING

Personal injury from hot surfaces

3.3.3.7 Heat fixture to 550F, and tighten the bolts when the solder is molten.

3.3.3.8 Let Fixture air-cool. Remove samples and inspect joint for excess solder on the surface. Make sure the cable width is within specs as it exits the solder fixture. Oversized cable due to solder penetration will cause problems in further assembly.

NOTE

Ensure unused solder is recycled or disposed of properly

3.3.4 Sample Assembly in Compression Fixture

3.3.4.1 Inspect the G-10 instrumentation wafers which contain voltage taps and spot heaters.

3.3.4.2 Assemble 4 samples according to the description below. Make note of the type of solder joint for the two pairs of cable. Typically a Type-B and a Type-C pair are assembled for each test.

3.3.4.3 The samples are mounted in a compression fixture which is illustrated in the figure below. The usual test arrangement involves four bare cable samples. As these are keystoned, (i.e., they are trapezoidal in cross-section), care is taken to alternate thick and thin edges so that pairs of conductors present parallel surfaces to the clamping faces. As indicated in the figure there are a series of separators: 0.76mm thick G-10 strips which carry electrical instrumentation described below, and 0.25 mm. thick Mylar strips which insulate adjacent samples of the upper and lower cable pairs.

3.3.4.4 Apply standard bolt torque using a calibrated torque-wrench as specified for the cable under test and the compression fixture being used.

3.3.4.5 Compression is applied by tightening 9.53mm (3/8 in.) bolts. These run along each side of the compression fixture at intervals of 25 mm. A torque of 51 N-m (230 inch-pounds) is used to tighten the bolts. This produces a clamping pressure of 70 Mpa (10 kpsi) for the 15 mm wide cables at room temperature. The pressure has been found to increase slightly at low temperature. With this method training behavior is limited to a few quenches. For other size cables this torque is adjusted. The torque setting is changed for other cable widths. Operator should verify the proper setting with the supervisor of the test.

3.3.4.6 Schematic cross-section of the compression fixture with the cable samples.

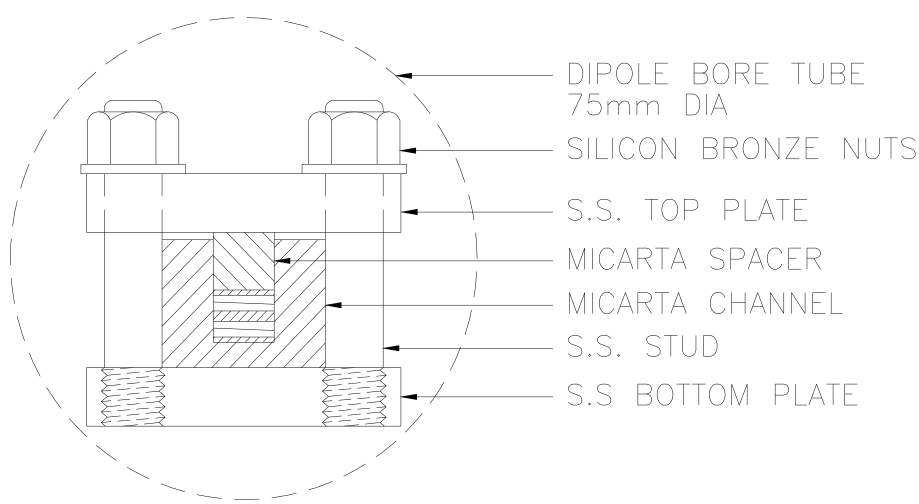


Figure 1

NOTE

The torque sequence should be repeated after a short period of time.

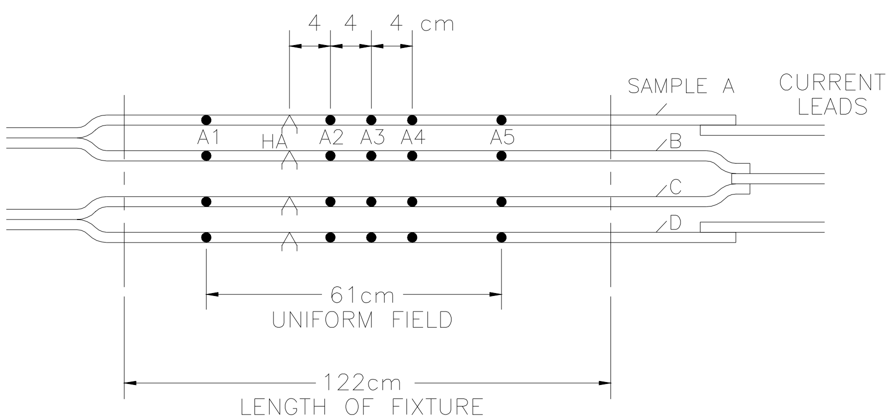
3.3.5 Connection to Sample Holder (Top Hat Fixture)

3.3.5.1 Connect the four samples to the 3 leads according to the figure shown below (Alternatively if only 2 samples are available connect to 2 leads.) The figure below shows schematically how the cables are connected to each other and to the gas cooled leads. The connections to the high current leads are made using ordinary soft solder over a 15cm length. A typical joint resistance is about 10^{-9} ohm.

NOTE

Ensure unused solder is recycled or disposed of properly

Figure 2



3.3.5.2 “StayBrite” silver-tin solder and paste flux are used. Carefully clean flux residues when finished.

3.3.5.3 Complete assembly by connecting the voltage tap terminals to the appropriate connector on the sample holder.

3.3.6 Measure Room Temperature Resistance (R295)

3.3.6.1 See the Reference Test Method for details of the measurement procedure and calculations.

3.3.6.2 Measuring current is 1A typically. Temperature accuracy required is 0.1 C.

Instruments used:

- HP 3497A DVM/Scanner
- Omega DP460T thermocouple E units
- HP 1 A Power Supply 6632A
- PC

3.3.7 Install Sample Holder Assembly in Test Cryostat

3.3.7.1 To avoid moisture condensation check that the cryostat is at room temperature around (297K).

3.3.7.2 Check with the cryogenic system-operator to see that the cryostat is isolated, and that the pressure has been properly vented .

3.3.7.3 Check the O-ring. Clean or grease it with Apiezon L type grease if necessary.

3.3.7.4 Using the crane lower the sample holder making sure to keep hands clear of pinch points.

3.3.7.5 Check that the torque-restraining fingers are correctly aligned with respect to test magnet field direction. Normal field orientation is field perpendicular to the wide face of the cable.

3.3.7.6 Position the sample leads so that leads do not short on surrounding surfaces.

3.3.7.7 Secure the sample holder to test cryostat top by installing four clamps.

3.3.7.8 Install liquid helium fill line making sure O-ring is in place.

3.3.7.9 Attach the gas-cooled leads, two 26 pin sample connectors and the three lead tap wires.

3.3.7.10 Install sample buss bars, checking that sample buss does not contact the surrounding surfaces.

3.3.7.11 Install magnet current leads to the active test cryostat and remove the leads form any others.

3.3.7.12 Turn on fan to maintain airflow to reduce frost on test cryostat top during cool down.

3.3.7.13 Have cryogenic-operator pump and purge test cryostat and then start LN2 cool down.

3.3.7.14 After using the jib crane, bring the hook back to its docking clamp so that the boom points south, this is so that the boom does not interfere with the overhead building crane.

3.3.8 Fill the dewar with liquid helium. “BNL-SSF-CRYO” computer used to monitor cryogenic status of the test station.

3.3.8.1 Control Room Operator should work in conjunction with the cryogenic-operator to satisfy the checklist given in Appendix A.

3.3.9 Low Temperature Resistance, R(10K)

This measurement may be done before or after the critical current determination described below. It is done at zero magnetic field. Typical measuring currents are at 6 to 10 kA. The low temperature measurement is a dynamic one, made by inducing a superconducting-normal state quench while the cable is carrying current. Referring to Fig. 2, a quench is triggered in Cable A, for example, by means of heater HA. The resulting waveform observed at nearby voltage taps, A2-A3 or A3-A4, consists of three parts: a superconducting state baseline voltage, a linear ramp voltage corresponding to the passage of the superconducting-normal interface between the voltage taps, and a slowly increasing signal characteristic of the normal state resistance. The latter increases in time due to normal state heating. However, at first the voltage is almost constant due to the residual resistance characteristic of the copper. Thus, there is a kink in the voltage waveform at the beginning and at the end of the linear ramp portion. The voltage difference between these two points equals the current times the residual resistance of the section of cable between the voltage taps. The resistance per centimeter is determined for the pair of taps (A2-A3) that are closest to the heater. The voltage onset for taps A3-A4 is used to pin-point the time at which the quench front reaches A3. The taps are relatively close to the heater in order to minimize the effect of current fall-off which results from the increase of normal state resistance as the quench propagates. Three measurements are taken at different currents and the results are averaged.

Instruments used:

- Nicolet digital oscilloscope, Model 4094
- 30 kA power supply (Rapid Electric, with BNL computer control circuitry)
- 2-Hazemeyer 15 kA DCCT current monitor
- Fluke 8520A DVM (Hazemeyer output)
- Pulsed power supply for sample- quench heater. 0-100 ms, 0-50 V, BNL circuit.

3.3.10 Critical Current Measurement

NOTE 1

The bath temperature is measured by means of two carbon glass resistance thermometers. These are placed on the top and bottom ends of the dipole (the magnet bore is vertical). The vapor pressure of the bath is also recorded.

NOTE 2

The sample current is supplied by two 15 kA supplies operating in parallel which are computer controlled by BNL circuitry. Sample current is monitored by two 15 kA Hazemeyer DC current transformers, secondary standard.

NOTE 3

The V-I curve of the sample, at a given field, is measured as the sample current is ramped at a fixed rate. All data acquisition is controlled by the "BNL-SSF-EXP" PC-computer and operated using the Short Sample Facility User Interface Program V1.1.1

3.3.10.1 The standard tests are performed at 4.4 K. The magnet is energized by a 8.5 kA power supply; a superconducting switch allows it to operate in the persistent mode. As the critical current of the cable will generally be in the range of 10–20 kA, two 15 kA supplies are operated in parallel to supply the cable test current. In addition to the power supplies and their controls and safety devices (quench detectors and fault detection circuits), the facility includes the instrumentation necessary for controlling the cryogenic environment and for measuring the critical current of the samples under test. Two computer systems are used: 1) a cryogenic system that monitors liquid helium levels, temperatures, and pressures and both sets and monitors the flow of helium through the gas-cooled leads, and 2) an experimental system for controlling the sample power supply, taking data, and storing data in the SQL database. The goal of the short-sample cable tests is to determine the transport critical current of the samples. This critical current is a function of temperature and the magnetic field. In order to obtain standardized results for a specified reference temperature and reference field, raw data is obtained for several applied fields with the samples at the temperature of the helium bath; that is, one acquires a set of critical currents, I_c, at bath temperatures, T_b, and applied fields, B_a, for each sample. By pairing samples which are believed to have similar properties, it is possible to acquire data on two samples simultaneously. Also, as there are three gas-cooled leads connecting the two sample pairs to the sample power supplies (see Fig. 2), four samples can be tested in a single cool-down, with the pairs being tested sequentially. To acquire the I_c data, the operator first sets the current in the dipole magnet for the desired applied field, then connects the sample power supply to the first sample pair to be tested.

3.3.10.2 Starting the Data Acquisition Applications

3.3.10.2.1 Two applications are run simultaneously to collect the data: 1) ShortSample.exe — a Visual Basic program, and 2) Ic-Acq66.ibw — a HP Instrument Basic for Windows application. Clicking the “Short Sample” icon on the desktop of the experimental computer (\\BNL-SSF-Exp) will load and start both these applications.

3.3.10.2.2 After both applications have completed loading, a dialog box will appear asking the user to select the number of sample power supplies to use, 1 or 2. Click 2.

3.3.10.2.3 The next dialog box asks the user to enter the number of the Active Cryostat, 4, 5, or 6. Click the appropriate number.

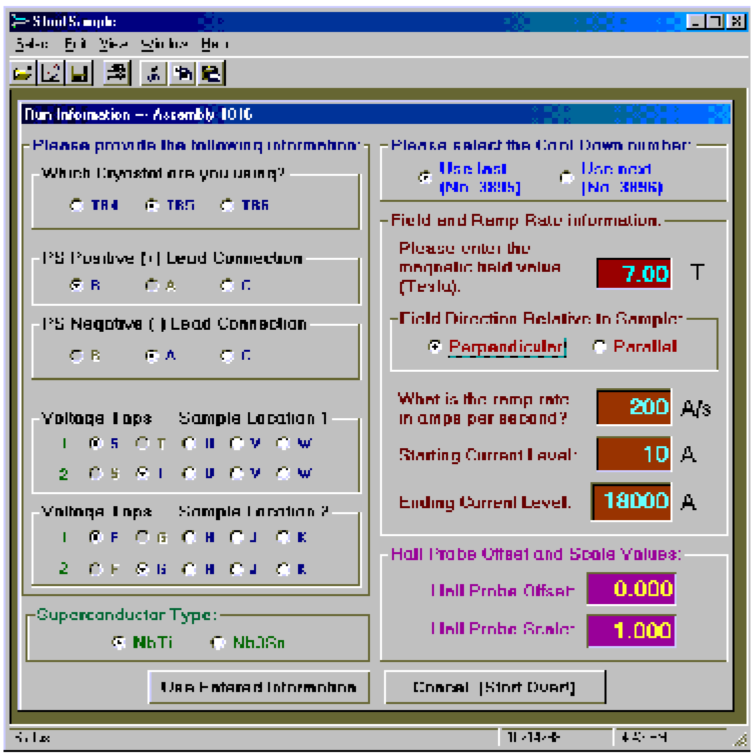
3.3.10.2.4 The ShortSample application will now synchronize the local and network databases.

3.3.10.2.5 The operator will now be asked to enter his or her Life Number or login name.

3.3.10.2.6 Click the “Opening Folder” icon in the ShortSample application. (Alternatively, the operator may click the “Select” menu item and choose the “Select Assembly” menu item.). A form will appear which allows the operator to select the cable assembly being tested. The data acquisition program has interacted directly with the database to provide a drop-down list of assemblies. They are listed in reverse order; the most recently assembled fixture appearing first in the list.

3.3.10.3 Testing

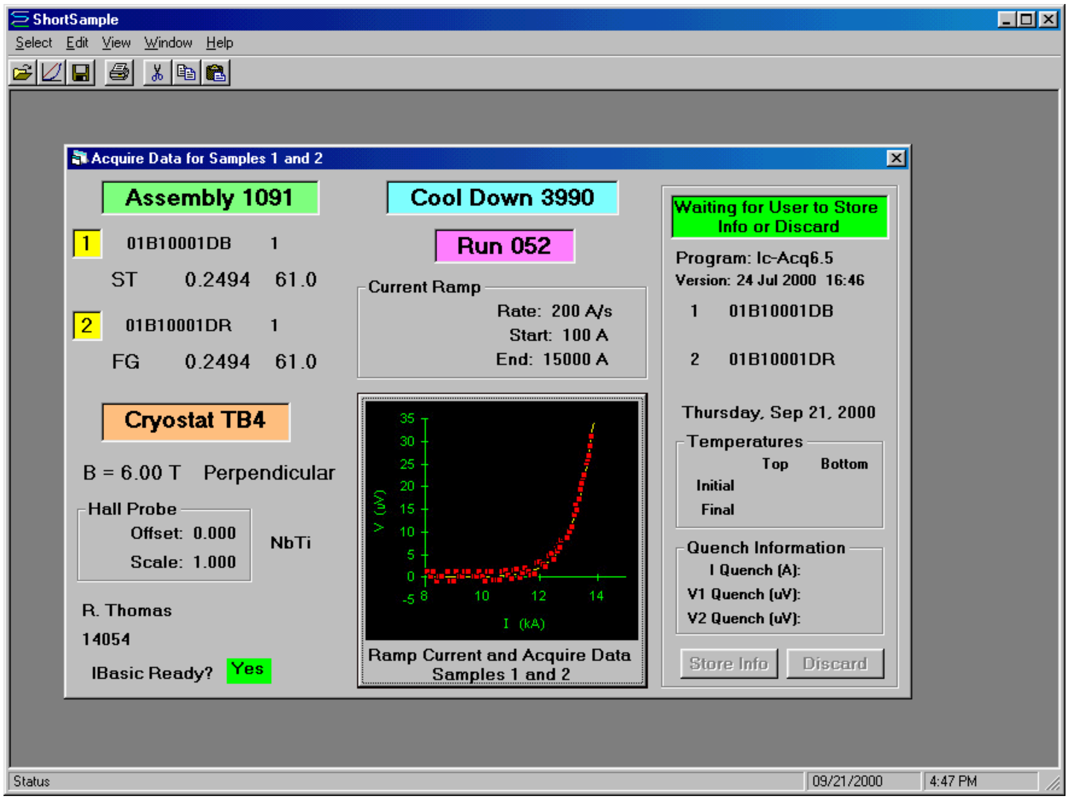
3.3.10.3.1 Enter the required information into the data acquisition program regarding the ramp rate and maximum current for the ramp, voltage taps, and other information on the form shown in Fig. 2. Then click "Use Entered Information." A new form will appear and the program will switch the focus to the Ic-Acq66.ibw application.



3.3.10.3.2 Enter the NPLCs to use. The instruments will be initialized.

3.3.10.3.3 Click "Start" to ready the DAC which will output the control voltage for the Sample Power Supply.

3.3.10.3.4 Click "Do Ramp". The ramp will execute.



3.3.10.3.5 Three high-resolution volt meters are triggered simultaneously as the current is ramped to obtain the voltage drops across the two samples and the current level as a function of time, as shown in Fig. 2.

3.3.10.3.6 Examine the data to determine whether a quench voltage was observed. If not, click “Start” again and repeat the ramp by clicking “Do Ramp.”

3.3.10.3.7 Once satisfactory data have been obtained and stored, return to the ShortSample application and click “Store Info”.

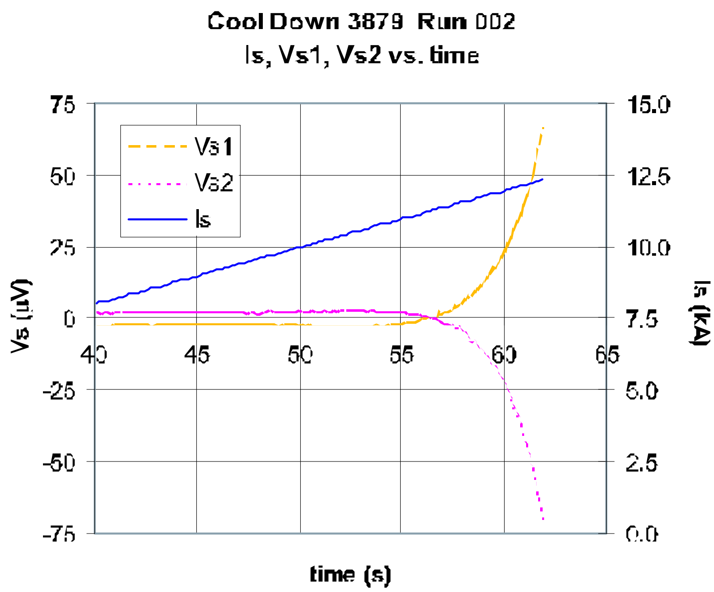
3.3.10.3.8 Perform an analysis of the acquired signals using the Ic-Acq66.ibw program. The analysis results will appear on the “Analysis Results” form in ShortSample. Click “Accept” or “Reject” and “Close” this form.

3.3.10.3.9 This completes a test cycle.

3.3.10.3.10 Repeat the testing cycle to acquire the number of sets of data at each dipole field level for each sample pair as specified in the Run Plan.

3.3.10.3.11 Change the field in the magnet, and collect sets of data at the new field level.

3.3.10.3.12 Repeat until testing has been completed for each of the fields in the Standard Run Plan - See Appendix C.



Actual signals for low-noise conditions.

3.3.11 Running the Magnet Power Supply Program

NOTE

See Appendix B for Additional Information

3.3.11.1 Goal of the Magnet Powering Procedure

The goal is to set the current in the superconducting magnet to produce the desired field for testing the cable samples, and then to place the magnet persistent current state and return the MPS to its parking current. In the persistent current state, the field produced is immune to power supply noise or current fluctuations and the field will remain nearly constant for long periods. (It will very slowly decay).

The superconducting magnet is in parallel with a superconducting short across its terminals. This short can be driven normal by a heater — the persistent current switch heater. In order to change the current in the magnet, the power to the persistent current switch heater must be on.

When the magnet is powered, the current windings experience huge Lorentz forces from the currents in the adjacent windings. If the forces cause a sudden movement of a section of the coil windings, the energy generated through friction can result in sufficient heating to cause that portion of the coil to go normal and the magnet will quench.

In order to reduce the probability of a quench, the current must be changed slowly, and as the field becomes larger, the ramp rate must be reduced even more.

When the magnet is in the persistent current mode and the MPS is being ramped to its parking current or back up to match the magnet current, the ramp rate can be much greater. But even though the magnet is in the persistent current mode, a very sudden and large change in the MPS current can cause the magnet to quench.

3.3.11.2 Initially Powering the Magnet

In order to power the magnet, the persistent current switch is driven normal by turning on the output of the power supply that heats the persistent current switch heater. The current in the magnet is then raised to the desired level through one or more computer-controlled ramps of the MPS.

A series of ramps is usually used with decreasing ramp rates in order to decrease the total time needed to reach the desired field level while avoiding high ramp rates that might quench the magnet.

Once the desired current has been obtained, the voltmeter reading the voltage across the magnet is observed. In about 20 s, this voltage will decay to the noise level of the power supply. As the persistent current switch is connected across the superconducting magnet leads, once the voltage has decayed to zero, it is safe to turn off the heater to the switch and allow it to become superconducting. As there is no voltage across the switch, there will be no current driven through it by the MPS.

When the switch has become superconducting, the MPS current can be reduced to its parking level. As the MPS current is reduced, the field produced by the magnet stays constant by transferring current to the superconducting path through the switch. [The field in the magnet can decrease only by reducing the current through the magnet coils, but a change in the magnet current would generate a voltage (~L dI/dt), and as the persistent current switch completes a perfect short (0 Ω) across the magnet, the current transfers to the path through this switch.] Since the forces on the wires of the persistent current switch are small compared to those on the magnet windings, this transfer can be performed by ramping the MPS current down at a higher ramp rate than was used to power the magnet.

3.3.11.3 Changing the Magnet Current

After all the critical current measurements have been performed at the set field level, in order to change the current in the magnet, the MPS current must first be set to match the current in the magnet. Again, this can be done at a higher ramp rate since the only current changing is the current through the persistent current switch. [The current in the magnet can't change, since to do so would require generating a voltage across the magnet equal to the back emf of ~L dI/dt, and the persistent current switch, acting as a superconducting short, ensures that the voltage across the magnet is always zero.] As the MPS current is ramped up, the field in the magnet stays constant while the current through the switch is driven to zero.

As the only way of knowing the current level in the magnet when it is in the persistent mode is through the effects of the magnet field that it produces, it is not possible to display the value of that current for the purpose of matching it with the MPS. Therefore the operator must keep track of the current level setting of the magnet.

Once the current level has been matched, the persistent current switch can be taken out of its superconducting state by turning on the output of the power supply for the persistent current switch heater. After waiting about 20 s, the power supply noise signal should appear on the voltmeter reading the voltage across the magnet, and it is safe to take the magnet to a new level (including reducing the current to 0).

It is again important to use ramp rates appropriate for the current changes that will take place in the magnet coils. If the current is being reduced to 0, a series of ramps of increasing ramp rate may be used in order to reduce the time required to take the magnet down to 0 A.

3.3.11.4 Introduction to the MPS Application

The magnet power supply program is a HP Instrument BASIC application that runs in the HP Instrument BASIC for Windows programming environment.

The version of the program is Version 2.1 and the name of the program is MPS2_1.ibw.

3.3.11.5 Loading the Program

The program is most easily started by clicking the icon on the Windows desktop shown on the Magnet Power Supply control computer, \\RHIC_902\BNL-SSF-Mag.

The program may also be started by starting up “HP Instrument BASIC” from the Windows “Start – Programs” menus. Then loading the file: “c:\\winapps\ibasic\programs\mps2_1.ibw,” and clicking “Run” on the HP IBW “Control Pad.”

3.3.11.6 Running the Program

When the program is started, a dialog box appears and the user is asked to click on the number of the Active Cryostat. Then two key labels appear: “MPS Ctrl” and “Exit.” Clicking “MPS Ctrl” takes the user to the parameter entry subroutine for entering the values for the ramp.

The values to be entered are:

- Ramp Rate in A/s
- Starting Current in A
- Ending Current in A
- F1, F2

Where F1 and F2 are:

F1 = the fraction of the total number of ramp points to be used for going linearly from a ramp rate of 0 A/s to the requested ramp rate (the roll-in), and
F2 = the fraction of the total number of ramp points to be used for going linearly from the requested ramp rate to 0 A/s (the roll-out).

Since the sum of F1 and F2 must be less than or equal to 1, the program will enforce that condition by requesting new values if that condition is not met.

The calculated current values to be clocked out by the DAC are based on the ramp rate for the three portions of the ramp. For example, if either F1 or F2 is 1 and the other is 0, the current will increase (decrease) quadratically from the starting current value to the ending current value, and only at the final current value will the ramp rate reach the requested ramp rate. (For all other points during the ramp, the ramp rate is smaller.) If F1 and F2 are both zero, then there is a linear ramp at the requested ramp rate from the starting current to the ending current.

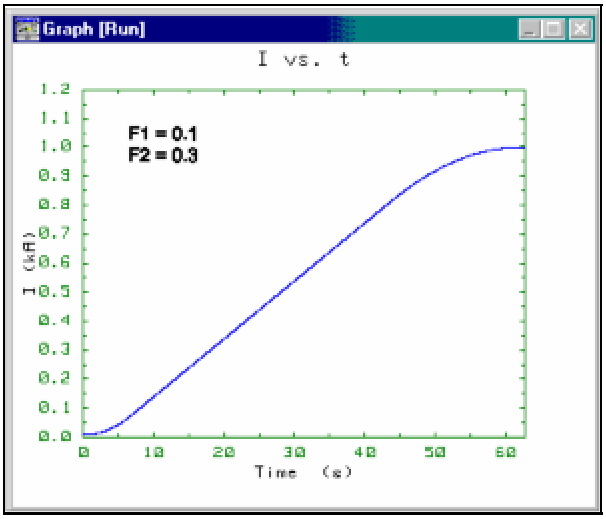


Figure 1. Up ramp at 20 A/s with F1=0.1, F2=0.3.

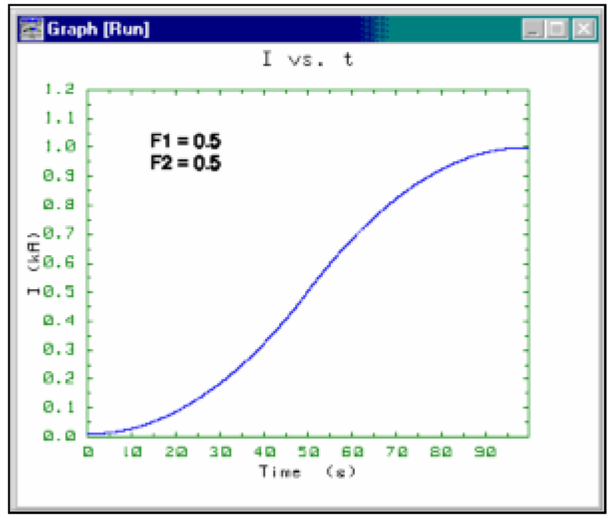


Figure 2 An up ramp with F1=0.5, F2=0.5.

After the parameters have been entered, the ramp values are calculated and downloaded to the DAC along with the rate at which the points are to be clocked out. A plot is shown in the "Graph" window of the ramp that will be generated, and a listing of the ramp parameters is shown in the "Alpha" window. The user should examine these, particularly the Ramp Time (the time to complete the ramp), before proceeding. Click the "ChgParam" button to change the parameters and generate new ramp values if the ramp is unsatisfactory. For further details regarding the ramp points, see Appendix A.

Two graphical panels will now also be visible. The Magnet PS Control panel displays the faults reported through the digital I/O input port of the DAC. It also shows the voltage across the magnet (not the PS output voltage) and the magnet current. A control on the panel allows switching the meter that is reading the voltage across the magnet from "DC" to "AC." The second panel displays information about the DC power supply for the heater for the persistent current switch. It shows the status of this DC supply and its output voltage and current. The values of voltage and current are coded into the program and depend on the Active Cryostat selection. A control on this panel allows turning the output of this supply "On" or "Off." [Caution: The buttons on these panels are only enabled at relevant times. Clicking the buttons will have no effect when the program is waiting for the user to enter ramp parameters, for example.]

3.3.11.7 To Power the Magnet Initially

In order to power the magnet, the heater for the persistent current switch must be powered so that the switch can be driven normal and the current path through the switch is resistive.

Click the “OUT on/off” button on the Switch Heater DC PS panel. A check mark will appear on the button and its color will change to red to indicate that the output of the DC PS has been connected to the heater circuit. The voltage and current read back from the DC PS will be displayed.

Wait about 20 s for the switch to be driven out of the superconducting state.

Click the “Start” soft key. (The soft keys are the eight buttons along the button of the “Alpha” window. You may also press the corresponding key of the keyboard, but this is not recommended, since the keyboard function keys do not have descriptive labels.) At this point, the program will take control of the two HP 34401A Multimeters (the ones reading the MPS current and the voltage across the magnet). Also, the Iotech DAC488HR will be put into a mode to be ready to begin clocking out the samples that have been stored in its memory.

Click the “Do Ramp” soft key. During the ramp, the program will continually read the multimeters and the status of the MPS and the DC PS powering the heater. If a hard fault is detected on the MPS, the ramp will stop and all instruments will re-initialize.

Soft key 6, labeled “Stop!”, may be pressed during the ramp to cause the ramp to stop at whatever current level it has reached at that point. During the ramp, the program is periodically requesting the DAC to tell it what memory location is being clocked out. If the ramp is stopped, the program retrieves the voltage reading from the last memory location that was clocked out and uses that value to determine the present current setting of the magnet. Ramping may then continue from this level. Once the ramp has completed, the operator may initiate another ramp using different ramp parameters. If the required field level has been reached, then the magnet may be put into persistent current mode.

To put the magnet into persistent current mode, first wait 20 s after the end of the ramp to allow the voltage across the magnet to decay to the PS noise levels.

Next, click the “OUTPUT on/off” button to turn off the power to the heater for the persistent current switch. The button will turn green and the current and voltage read back from the DC PS for the heater should be about 0.

Wait about 20 s for the switch to go into the superconducting state.

Click on "ChgParameters" and enter a ramp to take the MPS to its parking current at a relatively high ramp rate (~20 A/s).

Execute the ramp using the "Start" and "Do Ramp" soft keys.

3.3.11.8 Changing the Magnet Current When the Magnet is in the Powered Persistent Current Mode

In order to change the magnet current when it is operating in the persistent current mode, it is first necessary to match the current already going through the magnet coils.

Verify that the magnet has not quenched and that the system is a state to be powered. (The best indication that the magnet is at current when it is in the persistent current mode is through observing the effects of the magnet field that is being produced.)

Do not turn on the heater to the persistent current switch.

Enter and execute a ramp or a series of ramps that will take the MPS to the same current as the current in the magnet. Unlike the initial powering of the magnet, these ramps can be executed at relatively high ramp rates (~20 A/s).

At the end of the ramp that takes the MPS current to the same level as the current believed to be in the magnet, wait about 20 s.

Turn on the Output of the DC PS for the heater of the persistent current switch. Wait about 20 s. The MPS noise signal should appear on the meter showing the voltage across the magnet.

Execute a ramp or a series of ramps to take the magnet to the next desired current level. **The ramp rates must be appropriate for current changes in the magnet coils; that is, the ramp rates must be small if the magnet is at a high field.**

Once the desired level has been reached, put the magnet into the persistent mode and reduce the MPS current to its parking level using the same procedure as for initially powering the magnet above.

If the magnet current is being reduced to zero, leave the Output from the DC PS for the heater of persistent current switch on, and turn off the supply. The supply may be turned off by either clicking the "MPS Off" soft key or by manually pressing the "Off" button on the MPS Control panel in the instrument rack. Wait 20 s, then turn off the Output from the DC PS to the heater.

3.3.12 Removal of Sample Holder from Cryostat

3.3.12.1 To avoid moisture condensation be sure to check that cryostat is at room temperature around (297K)

3.3.12.2 Check with the cryogenic-operator to see that cryostat isolated and that the pressure has been vented.

3.3.12.3 Remove the sample buss bars, remove the gas-cooled lead lines, two 26 pin sample connectors and the three lead tap wires.

3.3.12.4 Remove the liquid helium fill line.

3.3.12.5 Remove the four clamps that hold the sample holder to the top of the test cryostat.

3.3.12.6 Using crane raise the sample holder making sure to keep hands clear of pinch points.

3.3.12.7 Cover the test cryostat opening with a micarta cover using the four clamps to secure it.

3.3.12.8 After using the jib crane bring the hook back to its docking clamp so that the boom points south. This is so that the boom does not interfere with the overhead building crane

3.3.13 Disassemble samples from compression fixture.

3.3.14 Archive samples.

3.3.15 Data Reduction and Analysis

3.3.15.1 The critical current is determined by computer aided graphical techniques on line and subsequently analyzed off-line using BNL developed software.

4 Quality Assurance Provisions

4.1 The Quality Assurance provisions of this procedure require that the technician shall be responsible for performing all assembly operations in compliance with the procedural instructions contained herein and the recording of the results on the production traveler.

4.2 The technician is responsible for notifying the technical supervisor and/or the cognizant engineer of any discrepancies occurring during the performance of this procedure. All discrepancies shall be identified and reported in accordance with RHIC- MAG-Q-1004.

Appendix A

Check List for control room testing

Before Fill Is Started

1. See that the sample leads are connected for the first sample to be tested.

2. Link box is in correct polarity.

3. Fan is on in the test station that is being run (the fan should be still on from night before).

During The Filling Of The Cryostat With Liquid Helium

1. Connector on dewar selection panel in the control room is sent to correct dewar.

2. The 5 Lead valves are open for the correct dewar.

3. Open valves for sample and for magnet lead flow on manifold.

4. Make sure that flow meters are full open (5 flow meters should be open).

5. Open the lead flows for magnet and sample from the control room cryo computer to pre cool the leads as the cryostat is filling.

6. Trickle control panel has the correct dewar selected and the trickle air valve is open for the correct dewar.

7. As cryostat is getting to level, set pressure to 18 or what is instructed for that run, then closely watch to see that it does not get over filled and change to auto (trickle fill). Close bottom fill.

Appendix B

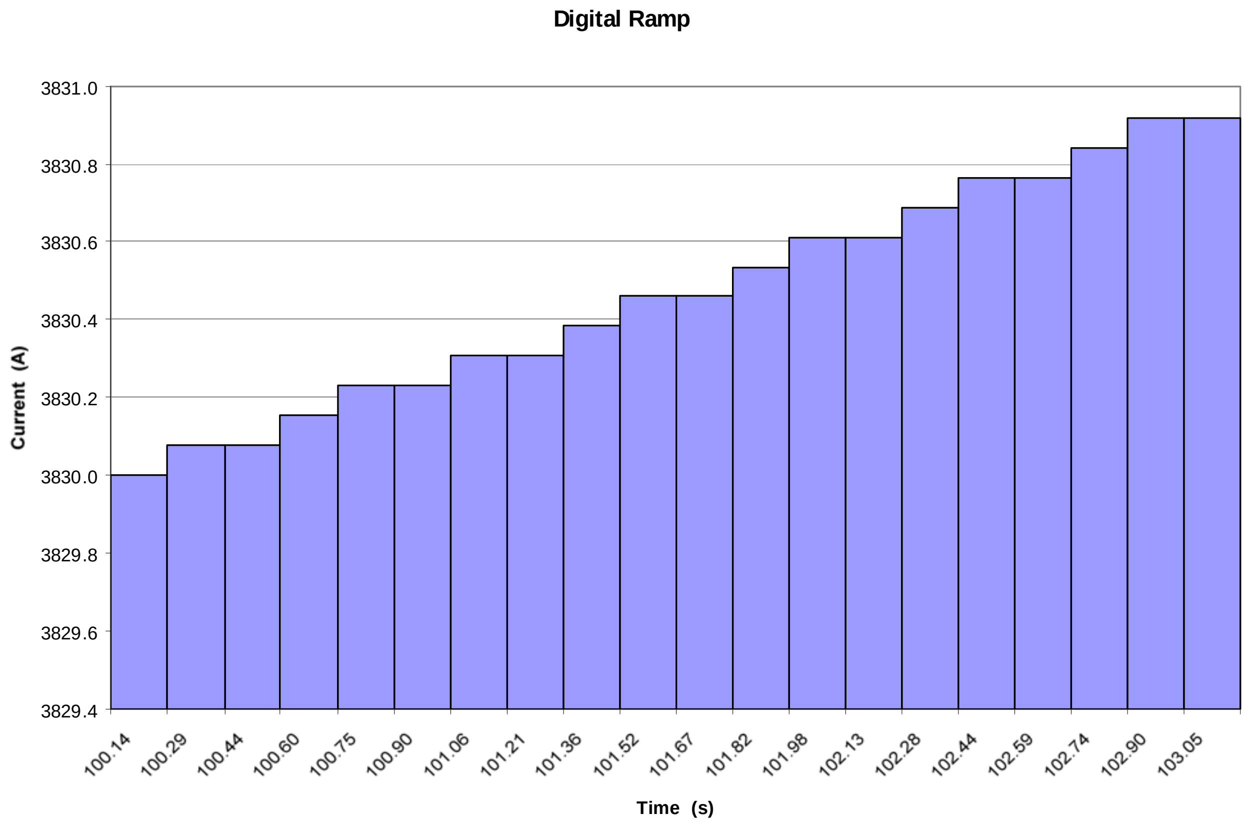
The Iotech DAC488HR is a 16-bit instrument with both unipolar and bipolar output ranges. For the MPS, we need a maximum output voltage of 5 V or less. Since (2^16)=65,536 and we are using a unipolar scale, a 1-bit change in DAC values, from one DAC sample to the next, corresponds to 0.0767 A (about 5 Volts/(2^16) * 1000., plus a little scaling to correct for the DAC calibration errors). [The factor 1000 is the A/V scaling of the magnet power supply — a 1 V control signal gives about 1000 A. For the DAC now in use, a factor of 1004.84 is needed in order to produce the requested currents as indicated by the Hazemeyer DC current transformer.]

The program will attempt to use as many ramp points as necessary in order that no two successive ramp values differ by more than 1-bit unless the total number of points would exceed 32,767. (Using more than 32,767 points results in long ramp calculation times.) Put another way, the program determines the minimum number of samples one needs for the requested ramp in order for the changes between samples to be 1 bit or less throughout the entire ramp. It doesn't help to have more samples for a ramp since you can't reduce the change from one sample to the next to less than a bit anyway. The program always attempts to do this, but is sometimes limited by the requirement of having no more than 32,767 samples to limit the calculation time. The DAC memory itself can hold up to 131,071 samples.

Any ramp, regardless of ramp rate, which has the same Istart, Iend, F1, and F2 will use the same points. So the calculated values of the ramp are stored according to “Istart-Iend” and if the same values are again requested *with the same F1, F2 values*, the original values will be reused. [If F1 or F2 differ, new values are calculated, and the file containing the old values for that “Istart-Iend” is overwritten.]

The clock frequency determines the maximum ramp rate. The ramp values can be clocked out at rates up to 100,000 samples/s or as slowly as 3 samples/s. [Actually, the DAC now in use been specially modified to allow output clock rates as low as 0.6 samples/s. IMPORTANT: If the unit in use is replaced by another DAC488HR, it is important to determine whether it has been specially modified to give low clock rates, and if not, to modify the MPS program accordingly.]

Since the DAC is a digital instrument, so it puts the new sample on its output at each tick of the clock. The voltage values on the DAC output don't really change smoothly. They produce a step function.



According to the manual, the settling time for the DAC is 6 :s, but due to the capacitances of the circuits to which the DAC output is connected, the magnet current certainly can't change as suggested by the "steps" in Chart 2.

The "instantaneous" ramp rate (produced by the 1-bit change when a new value is clocked out) as seen by the magnet depends on the time constants of the circuits to which the DAC output is connected.

In any case, if the noise on the control and feedback circuits of the magnet power supply is of the same order as the 76.7 :V maximum step change in the control signal, the rate of the magnet current changes is going to be some smeared out value anyway. (You get smearing from the capacitances, inductances, and resistances of the circuit, and that smearing gets submerged in the noise on the control circuits. As far as readback of the voltage across the magnet is concerned, if the noise is 100 :V, and the 1-bit step changes are happening slowly compared to the time the digital multimeter is taking to display a new reading, you may not see the individual step changes at all. You may just see the noise signal. But you will see the current signal continuing to increase slowly.)

For the types of ramps used for the magnets in the Short Sample Test Facility, an F2 smoothing value of 0.3 is enough smoothing, because for low ramp rates, when the difference between Iend and Istart is small, it doesn't matter whether there is a 1-bit step change every 4 or 5 clock ticks or whether there is one every 6 or 7 clock ticks — as you might get with a larger smoothing factor. Any changes, when they occur, are 1-bit changes in either case; they would just be farther apart in time.

When the difference between Iend and Istart is large, the 32,767 point limitation will come into play, and the minimum step changes will be larger, but in that case, it is expected that the system will be operating in a region where the magnet is not likely to quench.

Appendix C

Standard Run Plan for -Cables

1. Field Direction PERPENDICULAR
2. Note Polarity at Link-Box
3. Measure R(10K) values for one pair of cable samples
4. Take five temperature readings before energizing magnet
5. Temperature set to 4.4 to 4.45 K – 18 psi pressure setting.
6. Start at the first field specified for the type of cable being tested and in which test cryostat. See tables on next two pages.
7. Train sample to plateau current.
8. Take three V-I curves using the ramp rate specified.
9. Take V-I readings at the other fields specified in the testing plan
10. Change to the other sample pair and repeat test starting at the lowest field specified for the type of cable
11. Measure R(10K) values for the other pair