

## Princeton Plasma Physics Laboratory Procedure

Procedure Title: **Generic Electrical Test Procedure for NCSX Coils**

Number: <b>D-NCSX-PTP-CL-040</b>	Revision: <b>00</b>	Effective Date: <b>April 22, 2008</b> Expiration Date: <i>(2 yrs. unless otherwise stipulated)</i>
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### Procedure Approvals

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Responsible Division: **NCSX Project**

### Procedure Requirements Designated by RLM

LABWIDE:

<b>X</b>	Work Planning Form # (ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008, SEC.8 Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)	<b>X</b>	ES&H Review (NEPA, IH, etc.) <b>NEPA 1283</b>
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown	<b>X</b>	Pre-Job Brief
	Post-job Brief *		

D-SITE SPECIFIC:

	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Tritium Work Permit (OP-AD-49)		USQD (OP-AD-63)
<b>X</b>	Pre-Job Brief (OP-AD-79)		T-Mod (OP-AD-03)
	** DCA/DCN (OP-AD-104) # _____		

- \* Required for installations involving internal vacuum installations, critical lifts, and for the initial installation of repetitive work.
- \*\* OP-AD-104 was voided by procedure ENG-032. However, DCA's that were open at the time of adoption of ENG-032 are still considered valid for work approval purposes.

<b>REVIEWERS (designated by RLM)</b>		<b>Rec'd/ Incorp. Comments</b>
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<b>TRAINING (designated by RLM)</b>			
No training required <input checked="" type="checkbox"/> _____		Instructor _____	
Personnel (group, job title or individual name)	Read Only	Instruction <b>Pre-job Briefing</b>	Hands On
<b>Technicians performing task</b>		<b>X</b>	
<b>Quality Control Representative [optional]</b>		<b>X</b>	
<b>Training Rep.</b>			
RLM <b>Larry Dudek</b>			

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**RECORD OF CHANGE**

Revision	Date	Description of Change
00	4/18/08	Initial release

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**1 SCOPE**

**1.1 Introduction**

This document is a generic electrical test procedure that can be used for testing individual coils for the NCSX device. It describes the preparations, precautions and electrical test steps to be taken for the various types of coils on the NCSX device. [Modular coils, Toroidal Field Coils, Poloidal Field Coils and Trim Coils]

**1.2 Scope**

This procedure is used for performing various electrical tests on the individual coils on the NCSX device. It includes the following electrical tests:

- Inductance
- Capacitance
- Polarization Index [PI]
- Coil resistance [DC]
- Insulation resistance [Megger Test]
- Leakage Current: [Hipot Test]

**1.3 Identification of Coil being tested:**

Coil Type and ID Number: \_\_\_\_\_

**2 APPLICABLE DOCUMENTS**

- 2.1 ES&H Manual Section 2, Chapter 2.2.6- Safety Watch

**3 SAFETY REQUIREMENTS:**

All work will be performed in a safe manner in accordance with PPPL Environmental Safety & Health Directives **ES&H 5008** and the “Integrated Safety Management” (ISM) policy.

**3.1 Job Hazard Analysis:**

A JHA will be generated for the various preparation and testing activities. The JHA shall be reviewed by the Electrical Safety representative for accuracy as well as completeness. It will then be reviewed with all activity participants at the Pre-Job briefings.

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**4 PREQUISITES & CONDITIONS:**

**4.1 Pre-Job Briefing:**

A pre-job briefing will be held prior to performing any electrical tests. The briefing will describe the processes and safety issues [JHA] associated with procedure. Attendance shall be documented via training sign-in sheet.

<b>Pre-job Briefing complete:</b> _____ <div style="display: flex; justify-content: space-around;"><span>Test Director</span><span>Date</span></div>
---

**4.2 Coil Temperature and Recommended Sequence:**

These tests or any substrate of these tests may be performed on any of the coils being tested. The electrical tests will be performed at room temperature. If all of the tests are to be performed, a recommended sequence of tests is outlined below.

**4.3 Recommended Test Sequence:**

Recommended sequence of tests/measurements to be performed:

- Inductance
- Capacitance
- Polarization Index [PI]
- Coil resistance [DC]
- Insulation resistance [Megger Test]
- Leakage Current: [Hipot Test]

**4.4 Safety Requirements & Conditions:**

The following safety requirements and prerequisites shall be used whenever a PI Index, Megger or Hi-Pot electrical tests are performed.

4.4.1 All personnel performing these tests shall be familiar with the hazards and work procedure to minimize accidents that may occur.

4.4.2 A “Safety Watch” shall be appointed by the Test Director. The Test Director shall clearly describe to the Safety Watch his/her responsibilities.

<b>Name of Safety Watch:</b> _____  Responsibilities have been clearly discussed with Safety Watch:  <b>Verified:</b> _____ <b>Date:</b> _____ <div style="text-align: center;">Test Director</div>
--

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**4.4.2.1 Responsibilities of a Safety Watch** include as a minimum:

- a) Monitors the operations in an attempt to prevent careless or unsafe activities.
- b) Shuts down the power in case of an accident.
- c) Contacts ESU in case of accident
- d) Additional responsibilities of a Safety Watch can be found in the ES&H Manual Section 2, Chapter 2.2.6.

4.4.3 During the test, the “Test Area” shall be roped-off and suitable “danger high voltage” signs and flashing lights displayed.

Test Area has been safed:

**Verified by:** \_\_\_\_\_ **Date:** \_\_\_\_\_  
**Test Director**

4.4.4 The test operator shall stand on an approved tested electrical safety mat during the test operation.

4.4.5 Approved class 2 rubber electrical safety gloves shall be worn by test members during grounding operations which occur once the test has been completed, and the test equipment turned off.

4.4.6 **Coil Lead Cleanliness:** [Recommended] The Test Director shall verify that the coil lead area has been thoroughly cleaned of dirt prior to starting any electrical tests. It is recommended that the area be wiped with ethanol as the last cleaning operation.

Lead area has been cleaned and coil is ready for testing:

**Verified by:** \_\_\_\_\_ **Date:** \_\_\_\_\_  
**Test Director**

4.4.7 Once the test has been completed, turn off the test equipment and wait until the voltage drops to  $\leq 200.0$  volts. Then discharge the coil using a “Ground Hook”. After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the coil leads. [For modular coils, also attach a ground cable to winding form] The ground hook may be removed once the ground cable is in place.

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**5 TEST PROCEDURES**

This section is to be used for documenting electrical test. It includes specific test information including equipment identification, test result data and test authorization.

Test Director:

Test Director for this test or test series is: \_\_\_\_\_

\*\*\*\*\*

**5.1 Coil Inductance & Capacitance Measurements**

Due to the sensitivity of the Inductance tests, it is recommended that prior to testing the coil leads are connected together and grounded to the winding structure via clip leads and let set over night. This will ensure we have no capacitance build up in the coil

<b>Coil Type:</b>	<b>Coil No.</b>
<b>Test Location:</b>	<b>Test Date:</b>

<b>Test Equipment Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	<b>Test Date:</b>
<b>Temperature:</b>	<b>Humidity:</b>

<i>Special Test Conditions or Setup Requirements:</i>
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**Table 1-COIL INDUCTANCE/CAPACITANCE TEST DATA SHEET**

Frequency [Hertz]	100 Hz	1000 Hz
<b>Inductance Ls</b> [micro-henries] $\mu\text{H}$		
<b>Quality Factor [Q]</b>		
<b>Inductance Lp</b> [micro-henries] $\mu\text{H}$		
<b>Quality Factor [Q]</b>		
<b>Capacitance Cp</b> [micro-farads] $\mu\text{F}$		
<b>Dissipation Factor [D]</b>		
<b>Capacitance Cs</b> [micro-farads] $\mu\text{F}$		
<b>Dissipation Factor [D]</b>		
<b>Impedance Z</b> [Ohms] $\Omega$		
<b>Angle <math>\theta</math></b>		
<b>DCR</b> [Ohms] $\Omega$		

<b>Test Completed:</b> <b>Test Director Signoff:</b> _____ <b>Date:</b> _____  <b>Quality Control verify:</b> _____ <b>Date:</b> _____ [Optional]
---

\*\*\*\*\*

**5.2 Polarization Index [PI] Measurement**

The Polarization Index (PI) is a RATIO. Insulation resistance is taken at 1 minute (R1) and at 10 minutes (R10). The ratio R10/R1 is the PI. The test level shall be determined by the RLM depending on the coil or system being tested.

<b>Test Level:</b> _____ <b>Approved By:</b> _____
--

<b>Acceptance criteria: <i>Polarization Index [PI] &gt;4</i></b>
--

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5.2.1 Due to the sensitivity of the PI tests, it is recommended that for the modular coils, the leads are connected together and grounded to the winding structure via clip leads and let set over night. This will ensure we have no capacitance build up in the coil.

<b>Coil Type:</b>	<b>Coil No.</b>
<b>Test Location:</b>	<b>Test Date:</b>

<b>Test Equipment Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	
<b>Temperature:</b>	<b>Humidity:</b>

<i>Special Test Conditions or Setup Requirements:</i>
---

**Table 2-COIL POLARIZATION INDEX TEST DATA SHEET**

<b><i>Voltage Level:</i></b>	<b>G ohms</b>	
<b>PI =</b>	<b>TC:</b>	<b>nf</b>
<b>1 minute: ohms</b>	<b>Amperes</b>	
<b>10 minutes: ohms</b>	<b>Amperes</b>	

<b>Test Director Signoff:</b> _____ <b>Date:</b> _____
<b>Quality Control verify:</b> _____ <b>Date:</b> _____ [Optional]

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**5.3 Coil Resistance Measurement**

Measure the resistance of the coil at the terminal leads.

5.3.1 Acceptance Criteria:

**Acceptance criteria:** *As specified in Modular coil design specification [A, B and C]*

**Type “A” Modular Coil Resistance:** 10.97 milli-ohms

**Type “B” Modular Coil Resistance:** 10.73 milli-ohms

**Type “C” Modular Coil Resistance:** 9.01 milli-ohms

**Acceptance criteria:** *As specified in coil design specifications*

**Toroidal Field Coil Resistance:** 4.7 - 4.76 milli-ohms

**Poloidal Field [PF-1] Coil Resistance:** 2.8 milli-ohms

**Poloidal Field [PF-4] Coil Resistance:** 13.47 milli-ohms

**Poloidal Field [PF-5] Coil Resistance:** 17.21 milli-ohms

**Poloidal Field [PF-6] Coil Resistance:** 12.29 milli-ohms

**Acceptance criteria:** *As specified in coil design specifications*

**Trim [Type 1] Coil Resistance:** \_\_\_\_\_ milli-ohms **[TBD]**

**Trim [Type 2] Coil Resistance:** \_\_\_\_\_ milli-ohms **[TBD]**

<b>Coil Type:</b>	<b>Coil No.</b>
<b>Test Location:</b>	<b>Test Date:</b>

<b>Resistance Test Equipment Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	<b>Test Date:</b>

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<b>Temperature Measurement Equip. Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	
<b>Temperature:</b>	<b>Humidity:</b>

5.3.2 Using the bridge probe, make pressure contact on the ends of the coil leads being tested.

**Record the resistance readings in** Error! Reference source not found..

5.3.3 Place temperature sensor on the surface of the coil leads and record the temperature of the copper after the reading stabilizes.

$$R_{20} = \frac{254.5}{234.5 + T_c} \times R_c$$

Where:  $R_c$  = measured resistance of the conductor (milliohms)

$T_c$  = temperature of coil when resistance measurement is made (C°)

**Table 3- MEASURED COIL RESISTANCES**

<b>Measured System Resistance (<math>R_c</math>) mΩ at <math>T_c</math></b>	<b>System Resistance corrected to 20 C° (<math>R_{20}</math>)</b>	<b>Calculated System Resistance @ 20 C° [per coil specification]</b>
<b>Rc:</b>		See accept. criteria
<b>Temp C:</b>		

**Resistance Results:** *Acceptable:* \_\_\_\_\_ *Unacceptable:* \_\_\_\_\_

<b>Test Director Signoff:</b> _____ <b>Date:</b> _____
<b>Quality Control verify:</b> _____ <b>Date:</b> _____ [Optional]

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**5.4 Insulation Resistance Measurement- [Megger Test]**

5.4.1 Acceptance Criteria:

<b>Acceptance criteria:</b> <b>Coil Insulation Resistance: &gt;1K Meg ohms</b>
---

**Table 4- TEST VOLTAGE LEVELS**

<b>Coil Type</b>	<b>Manufacturing Test Voltage</b>	<b>Maintenance Field Test Voltage</b>
Modular Coil	<i>7500 volts</i>	<i>5000 volts</i>
PF Coils [PF4-6]	<i>7500 volts</i>	<i>5000 volts</i>
PF Coil [PF1]	<i>5000 volts</i>	<i>5000 volts</i>
Toroidal Field Coil	<i>13,500 volts</i>	<i>9000 volts</i>
Trim Coil	<i>4500 volts</i>	<i>3000 volts</i>

<b>Coil Type:</b>	<b>Coil No.:</b>
<b>Test Location:</b>	<b>Test Date:</b>

<i>Maximum Voltage Level:</i> _____ <b>Approved by RLM:</b> _____
---

<b>Test Equipment Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	
<b>Temperature:</b>	<b>Humidity:</b>

<i>Special Test Conditions or Setup Requirements:</i>          
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5.4.2 Complete the steps below and perform the insulation resistance test [Megger].

- Test director shall verify that all safety requirements and prerequisites per section 4.4 have been performed prior to starting the test.
- Place the Megger test set on a firm, stable surface.
- Securely connect a ground cable between building steel and the test unit.
- Connect the Megger ground lead to the ground plane. [For the modular coils ground the winding form and copper chill plates]
- Connect the Megger power lead to the coil leads.
- Measure the insulation resistance to ground. The test results shall be in compliance with the requirements noted in Section 5.1.10.

5.4.3 Upon completion of test turn off the test equipment and wait until the voltage drops to  $\leq 200.0$  volts. Then discharge the coil using a “Ground Hook”. After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the winding form and the coil leads. The ground hook may be removed once the ground cable is in place.

**Table 5- MEGGER TEST RESULTS**

Test Voltage	Test #1 Insulation Resist. Minimum 1KMΩ	Test #2 Insulation Resist. Minimum 1KMΩ	Observations
500			
1000			
2000			
3000			
4000			
5000			
6000			
7500			
8000			
9000			
10,000			
11,000			
12,000			
13,000			
13,500			

**Megger Results: Acceptable:** \_\_\_\_\_ **Unacceptable:** \_\_\_\_\_

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<b>Test Director Signoff:</b> _____	<b>Date:</b> _____
<b>Quality Control verify:</b> _____ [Optional]	<b>Date:</b> _____

**Comments:**

\*\*\*\*\*

**5.5 Insulation Current Leakage Measurement- Hi Pot Test**

Perform the hi-pot test [DC high voltage and leakage test] to confirm the integrity of the Coil insulation to ground.

5.5.1 Acceptance Criteria:

**Acceptance Criteria:**  
Maximum coil Leakage Current:  $\leq 10$  *micro amps*

**Table 6-TEST VOLTAGE LEVELS**

Coil Type	Manufacturing Test Voltage	Maintenance Field Test Voltage
Modular Coil	5000 volts*	5000 volts
PF Coils [PF4-6]	13,500 volts	9000 volts
PF Coil [PF1]	9000 volts	9000 volts
Toroidal Field Coil	13,500 volts	9000 volts
Trim Coil	4500 volts	3000 volts
	* Limit set by Project	

<b>Coil Type:</b>	<b>Coil No.:</b>
<b>Test Location:</b>	<b>Test Date:</b>

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<b>Maximum Voltage Level:</b> _____ <b>Approved by RLM:</b> _____
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<b>Test Equipment Name:</b>	<b>Equipment S/N</b>
<b>Calibration Date:</b>	
<b>Temperature:</b>	<b>Humidity:</b>

<b><i>Special Test Conditions or Setup Requirements:</i></b>
--

- 5.5.2 Complete the steps below and perform the insulation leakage test [Hi-Pot] of the coil at the coil leads.
- Test director shall verify that all safety requirements and prerequisites have been performed prior to starting the test.
  - Place the Hi- Pot test set on a firm, stable surface.
  - Securely connect a ground cable between building steel and the test unit.
  - Connect the Hi Pot ground lead to the coil ground plane. [For the modular coils ground the winding form and copper chill plates]
  - Connect the Hi Pot power lead to the coil leads.
  - Measure the current leakage to ground. The test results shall be in compliance with the requirements noted in Section 5.1.11.3.
- 5.5.3 Upon completion of test turn off the test equipment and wait until the voltage drops to  $\leq 200.0$  volts. Then discharge the coil using a “Ground Hook”. After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the ground plane and the coil leads. The ground hook may be removed once the ground cable is in place.

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**Table 7- COIL HI-POT TEST RESULTS**

Voltage Level Volts	Leakage Current @ 0 seconds	Leakage Current @ 30 seconds	Leakage Current @ 60 seconds	Remarks
500				
1000				
2000				
3000				
4000				
5000				
6000				
7500				
8000				
9000				
10,000				
11,000				
12,000				
13,000				
13,500				

<p><b>Test Director Signoff:</b> _____ <b>Date:</b> _____</p> <p><b>Quality Control verify:</b> _____ <b>Date:</b> _____</p> <p>[Optional]</p>
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<p><b>Comments:</b></p>
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