PRINCETON PLASMA PHYSICS LABORATORY

NATIONAL COMPACT STELLARATOR EXPERIMENT

COIL TEST FACILITY

PROJECT HAZARDS ANALYSIS
(NCSX-PHA-142-02-00)

Rev. 0, March 9, 2005

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1.0 Overview of Operation

The Coil Test Facility (CTF) has been conceived by NCSX project engineers to serve as a utility allowing the safe use of a 2000 volt (open circuit) 48 kA D-Site power supply pair to perform power tests on NCSX coils; both prototype and production assemblies. The CTF will be fitted with an LN_2 supply to cool winding assemblies to 80K between pulses.

A separate coil test plan will be provided and maintained by the NCSX Project and will describe the particular scenarios necessary to achieve Project goals and objectives.

2.0 Reference Documents

ESHD 5008 - PPPL Environment, Safety, and Health Directives (“Safety Manual”)

6000-B-52006-PL, Rev. 17, LP-362

6000-D-59077K1, Rev. 1, Energy Conversion Systems, NCSX Coil Test Facility, Key Interlock System Schematic

6000-D-59076K1, Rev. 6, Key Interlock Schematic, TFTR SLD

B-4A2002, Sh. 77, Rev. 8, TFTR – Installation Notes, Grounding Notes, Grounding Connectors and Symbols

B-4A2002, Sh. 33B, Rev. 8, TFTR – Installation Notes, Grounding Notes, Grounding Connectors and Symbols

B-AE2006, Sheet 511, Rev. 6, NSTX CHI System Overview - EM

B-4FD100, Rev. 0, Power Systems, NCSX Coil Test Facility, CTCB-EE-500 AC Power CWD

B-4FD101, Rev. 0, Power Systems, NCSX Coil Test Facility, Lighting AC Power CWD

B-4FD105, Rev. 0, Power Systems, NCSX Coil Test Facility, Switch S1 Indication and Ground Sol

B-4F1005, Sheet 1571, Rev. 8, NSTX CHI-Phase I, CHI Schematic Diagram

B-4F1005, Sheet 1575, Rev. 8, NSTX CHI-Phase I, CHI Control Wiring

B-4F1005, Sheet 1576, Rev. 10, NSTX CHI-Inner Electrode Ties to OH Ground Plane, Tension Tube & TF Hubs

D-4FD104, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Grounding Schematic

D-4FD111, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Gate Support Weldment

D-4FD113, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Gate Assembly/Detail

D-4FD114, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Enclosure Weldment and Cutouts

D-4FD115, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Ground Switch Bus Details

D-4FD118, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Gate Support

E-4FD001, Rev. 8, Energy Conversion Systems, (TFTR) Test Cell Basement EL78, Tray Layout in Transition Area

E-4FD002, Rev. 9, Energy Conversion Systems, (TFTR) Test Cell Basement EL78, Tray and Conduit Layout

E-4FD103, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Tray and Conduit Arrangement

E-4FD112, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Gate Support Assembly/Installation

E-4FD116, Sheet 1 of 2, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Ground Switch Enclosure Assembly

E-4FD116, Sheet 2 of 2, Rev. 0, Energy Conversion Systems, NCSX Coil Test Facility, Ground Switch Enclosure Assembly

M-4F1079, Rev.4, Energy Conversion System, Energy Conversion Building, Grounding Plans EL87'-2 & 118'-9

3.0 <u>Description of System</u>

The CTF (see Figure 1) is an enclosed electrical test area located in the D-Site Test Cell Basement having a grounded metal exterior. The DC power for the planned coil tests is sourced from the NSTX counter helicity injection (CHI) power supplies in the FCPC building (see Figure 2). These four power supply sections, when configured for maximum output, can generate an open circuit potential of 2 kV and a current of 48 kA. These power supplies will receive their waveforms from the NSTX control room and will operate in tandem with NSTX machine pulses. A future evolution of this system, <u>not yet reviewed or RLM-authorized</u>, will allow CTF pulses when NSTX is down for major maintenance.

The output of the CHI rectifier power supplies is routed to the safety disconnect switch (SDS) assemblies that house the slow disconnect and the fast ground switches specific to the CHI supplies (see Figure 3). The normal (safe and not operating) state of the SDS assembly is that of line switch open and ground switch closed, which protects the outside world from inadvertent rectifier voltage.

Figure 1
Coil Test Facility Enclosed Area

Figure 2
CHI Power Supplies

Figure 3, Safety Disconnect Switch Cabinets Containing Slow Bus Disconnects and Fast Ground Switches

The SDS's use compressed air in their actuators to move the disconnect and grounding switches from the normal (safe) state to the operational state. The compressed air necessary to "unsafe" the system and prepare for operation is supplied through the safety lockout device (SLD) shown in Figure 4. Suggested by its appearance, the SLD is primarily an air valve fitted into an array of electrical and key-sequenced interlocks. Complex and deliberate behavior is required to allow the provision of compressed air to the SDS's and will be outlined in Section 5, Operation Description.

Figure 4
Safety Lockout Device

Figure 5 shows a newly installed enclosure containing a manually operated DC disconnecting and grounding switch existing downstream of the SDS's (Figure 3) and upstream of the test area (Figure 1). The function of this switch is to allow access to the test area when the SLD is "pressurized"; passing air to the SDS's allowing NSTX operations. Access to the test area is not afforded unless the CTF switch of Figure 5 has both disconnected the power bus and has grounded the test area and incoming bus and its connected load. Moving the CTF switch to disconnected and grounded state releases a sequencing key that allows access to the CTF test area.

The CTF design includes cryogenic cooling of the inductors to be exercised in the test area. The urethane foam insulated delivery line will transport LN_2 from the Neutral Beam cryogen supply to the test area. Figure 6 shows a small insulation test module being cooled to LN_2 temperature in a manner similar to the eventual operation in the CTF. The exiting gas plume shown to the right of the module in Figure 6 is similar to the larger plumes that will be collected within the CTF by a dedicated HVAC exhaust duct that eventually discharges out through the D-Site stack chase.

Figure 5
CTF Grounding and Disconnect Switch Enclosure

Figure 6
Cryostat/Insulation Test Module

4.0 Hazards

The PPPL ES&H Directives provide a thorough listing of hazards encountered during construction and experimental operations at PPPL as well as those in office settings. Important, significant, yet routine hazards such as hand tool misadventures or ladder accidents are not addressed in this analysis.

The Peer Review entitled ES&H Aspects of the Coil Test Facility, held on April 5, 2004 focused on three main themes: Electrical/magnetic Safety; cryogenic safety; and chemical safety.

4.1 Electrical Safety

The 2kV DC, 48 kA power supplies pose a voltage hazard and clearly have the driving power to generate destructive faults at an overheated connection or poorly supported conductor. The Engineering Department has designed competent key-sequenced exclusion zones with grounded barriers to protect personnel from electrical hazards. These engineered provisions are consistent with the resident practices at PPPL and have been both design reviewed and QC'd in the field.

4.2 Magnetic Safety

The Engineering Department has performed magnetic field calculations for the first test specimen; routinely referred to as the "NCSX planar racetrack coil." The calculations are summarized by R. Hatcher in a 2/23/05 memorandum to the NCSX Project Team. The calculated fields at 15 feet from the coil are consistent with the limits listed in the ES&H Directives, Section 4.7, Magnetic Field Safety, Table 1 and Section 4.8, Safety for Pacemaker Wearers, Statement 4.8.1A. A rope barrier will be established at 15 feet for pacemaker wearers.

A new calculation will be required for each test (coil) configuration. The daily ops checklist will have a sign-off for a relevant magnetic field calculation reference.

4.3 Cryogenic Safety

The CTF uses LN_2 to cool structures to approximately 80K to establish conditions for NCSX-relevant testing. Touch injuries are possible if personnel are inattentive or do not manage insulation well. All cryo lines will have pressure relief elements to accommodate any valving mis-operation. A dedicated, positive draft nitrogen gas ejection line is being constructed to remove the 200 cfm of boil-off gas expected from high power modular coil operations in CY 2005 and beyond. Resistive heaters will be applied, if necessary, to the ejection line to prevent icing.

4.4 Chemical Safety

Consistent with ES&H guidance at PPPL, every effort has been made to minimize the use of hazardous chemicals in the construction and eventual operation of the CTF. One class of products without a currently known and less hazardous alternative is the family of expanding closed cell polyurethane insulating foams.

Polyurethane foam is particularly useful in the construction of cost-effective insulation for cryogenic systems. One component of these foaming products, known sometimes as methylene di-isocyanate, has toxicity levels that draw particular interest at PPPL and with Princeton Site Office oversight.

All use of expanding closed cell polyurethane insulating foams will be done with deliberate and fully disclosed ES&H Division coordination.

4.5 Likely Operational Events

Table 1 provides a description of off-normal events that may occur in the lifetime of the CTF.

CTF Operating Mode	Failure Mode/Cause	System Effect	Fault Detection/ Isolation	Compensation Provisions	Remarks
Locked up, power testing	Bus/cabling joint failure Test specimen failure	Degradation (possibly extreme) of electrical joint or apparatus	D-Site smoke detection equipment and human observation, both visual and aural	None – Render system safe and repair	ES&H relevance – Personnel cannot access buswork during power operations. Observer is stationed outside a procedure-specified exclusion zone
LN_2 system operating	LN_2 leak to atmosphere	Possible depression of local atmospheric oxygen levels	Audible O_2 monitor alarm and visual observation	None – Evacuate area if alarm actuates, remotely de-energize LN_2 feed, restore compliant atmosphere, repair fault	ES&H relevance – O_2 monitor required in CTF enclosure when LN_2 is not locked/tagged out
LN_2 system operating	Loss of dedicated gaseous nitrogen ventilation system	Possible depression of local atmospheric oxygen levels	Audible O_2 monitor alarm and visual observation	None – Evacuate area if alarm actuates, remotely de-energize LN_2 feed, restore compliant atmosphere, repair fault	ES&H relevance – O_2 monitor required in CTF enclosure when LN_2 is not locked/tagged out

Table 1
CTF Likely Failure Modes and Effects Analysis

5.0 Operation Description

The CTF will be energized in a manner that closely resembles the “searched and secured” methods used on PBX-M, TFTR, and NSTX. Using a daily checklist from an approved OP-G-class procedure, the securing personnel will clear the test area's enclosure of personnel and close and lock the enclosure door. The locked status of the door will allow the sequencing key to be used in the process of rendering the CTF "unsafe" and ready for pulsing.

Flashing red lights will be posted around the CTF and physical barriers will maintain an exclusion zone around and outboard of the CTF's grounded metal walls. Figure 7 shows a portion of the test cell basement that will be inside the zone. The zone serves at least two functions: 1) Inadvertent access to the enclosed-and-grounded overhead DC bus tray is prevented; and 2) A flash and percussion buffer distance is afforded in the unlikely event of a gross failure. An observer will be stationed outside of the barriers to announce unexpected events over the FM radio system.

Figure 7
Portion of Test Cell Basement in Front of Enclosure to be Included in the CTF Exclusion Zone

A suite of guiding procedures including administrative, Kirk key checkout, enclosure access, and operating types will be produced in compliance with PPPL Engineering Department Procedure ENG-032, PPPL Technical Procedures for Experimental Facilities, Rev.1.