

National Compact Stellarator Experiment
Safe Startup and Control Plan

NCSX-PLAN-SSU-01

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NCSX Safe Startup and Control Plan

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RECORD OF REVISIONS

Revision Number	Date	Description of Changes
0	6/13/2006	Initial Issue
1	3/31/2008	Updated to reflect current status and plans

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1.0 PURPOSE

1.1 The purpose of the NCSX Start up and Control document is to depict those controls, actions, documents, procedures, and ES&H requirements necessary to meet the CD-4 requirements for the Stellarator Acceptance Testing and Magnetic Configuration Studies phase of the NCSX Project.

2.0 SCOPE

2.1 The safety of personnel and the safety of the device (NCSX) through the startup and commissioning phase are critical to the success of the project. Items associated with electrical safety, cryogenic safety, industrial safety, infrastructure safety, and machine safety are key functions / elements detailed in this document. The scope of this document is to maintain personnel, and equipment safe throughout the startup process leading to first plasma.

3.0 REFERENCES

Table 3-1 List of References

Reference	Title
ES&HD 5008	PPPL ES&H Manual
NCSX SAD-(TBD)	NCSX Safety Assessment Document
OP-NCSX-(TBD)	Preparation of NCSX Areas For Machine Operations
OP-NCSX-(TBD)	NCSX Machine Operation Guide for Startup and Shutdown
ISTP-(TBD)-001	Integrated System Test Procedure Startup & Commissioning
ENG-030	PPPL Technical Procedures for Experimental Facilities
ENG-032	Work Planning Procedure
ENG-036	Control of Temporary Modifications
OP-AD-09	Work Permits (C Site & D-Site)
OP-AD-56	Control of Equipment and Status
DOE 5480.19	Conduct of Operations Requirements for DOE Facilities
ESH-004	Job Hazard Analysis
ESH-016	Control of Hazardous Energy Sources via Lockout/Tag Out

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ENG-011	Interlock Key Control
OP-AD-24	Experimental Area Cleanliness
OP-AD-39	Conduct of Operations

4.0 NCSX PERSONNEL SAFETY

The following personnel safety controls will be in place in support of startup. Note: The level and manner of protection for personnel safety and administrative control will meet or exceed that which was successfully employed at TFTR and NSTX.

4.1 Safety Interlock Systems

NCSX will incorporate a Central Safety Interlock System (CSIS) which will provide centralized control and monitoring of high energy subsystems and hazardous areas. For first plasma this system will be implemented in a hardwired manner resembling the TFTR and NSTX Hardwired Interlock System (HIS).

The CSIS configuration for first plasma operation will integrate the following components in a fail-safe manner:

- Hardwired control elements. Key Switches, relays, and indicator lamps (control system) will be employed to control and annunciate the configuration of the device and ancillary equipment.
- Global E-Stop Buttons. Upon activation will shift all appropriate energy sources to a SAFE (zero-energy) state.
- Kirk-key mechanical/interlocking/captive locks required (per ENG-011).
- Redundant door monitors will be part of a "safety loop". If the safety loop is inadvertently "broken" (i.e., opening a door or safety enclosure) appropriate systems will shift to a SAFE (zero-energy) state.
- Electrical-isolation to bridge safe/hazardous areas.
- An Access Control System (ACS), see below.
- Permissive signals to the C-Site ESAT Power Supplies:
 - Enabling Permitted
 - Arming Permitted

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- No Global E-Stop
- Annunciation signals from the C-Site ESAT Power Supplies:
 - Disabled
 - Disarmed
 - Shutdown

4.2 Access Control System

Similar to TFTR and NSTX, the NCSX will incorporate an Access Control System (ACS) which will control access to hazardous areas. It will be comprised of the following elements:

- Card Reader(s). As on NSTX, only qualified/trained personnel will be authorized for unescorted access into the Test Cell. The card reader will be part of PPPL's Access Control and Monitoring System (ACAMS).
- Door Monitor and motion sensor. The door will be monitored in the typical manner. An alarm to security will be sent upon forced entry. A motion sensor will be positioned inside the test cell to suppress the forced-entry alarm when personnel leave the area.
- An interface with the CSIS. The card reader's control of the door strike/lock will be interlocked with the CSIS such that the door strike will be enabled only when the Test Cell is 'Safe' and the ACS is in the 'Access Permitted' mode.
- Egress from the Test Cell and other interlocked hazardous areas will not be impeded by the ACS or CSIS.

4.3 Oxygen Monitors

Oxygen monitors will be provided in the NCSX test cell to monitor for leaks in the cryostat which may lead to an oxygen deficient environment (ES&HD 5008 Section 8, Chapter 5). These monitors will provide an audible alarm thus providing a loud annunciation which can be heard outside of the NCSX Test Cell.

4.4 Cryogenic Safety

Cryogenic operations when filling and operating the NCSX cryostat will conform with the safe handling requirements of cryogenics (ES&HD Section 9, Chapter 3).

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5 NCSX MACHINE SAFETY

5.1 Power System And Coil Protection Design Basis

The design basis of the power system / coil protection shall be the following;

- The NCSX Coils will use the shunts for current measurements in the C-Site power supplies that feed the coils.
- The coils will employ the built-in protection in the C-Site Rectifiers.

The Machine coils are being fed from C-Site power supplies of limited capability as compared to the coil ratings. The built-in protection in the power supplies is adequate to protect the coils. Additionally we are augmenting this through features described in the sections that follow.

5.1.1 C-Site Protective Features

The following C-Site rectifiers protective features/parameters (operational function status) shall be available during startup:

- Cooling water flow loss;
- SCR Over-temperature;
- SCR Junction temperature high;
- Conversion transformers Primary Instantaneous Over-current;
- Conversion Transformers Over-temperature;
- Rectifier door interlock to trip primary AC input in case door is opened;
- Over/under AC voltage conditions;
- DC output over current;
- DC output over voltage;
- MOVs and CR snubbers to suppress over voltages (**NOTE: The settings of the currents in these units will be such that the coils will not be overloaded**)

5.1.2 Additional Coil Protection Based on PLC Logic

Additional Coil Protection based on PLC logic will include the following power supply arm permissive protection:

- Power supply enable command must be high;

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- Power supply must be enabled (contactor limit switch feed back);
- No thermal trip on corresponding coil;
- Corresponding disconnect switch ready permissive;
- Corresponding disconnect closed;
- Computer arm command high (the computer arm command is issued n seconds before the shot and removed n seconds after the shot. This can be bypassed by the operator
- Remote interlock – Coil temperature normal for start - In the initial phase of the project this signal is given manually by the operator in accordance with approved procedure.
- Temperature signal from Cryostat normal

5.1.3 Common Power Supply Enable Permissive Protection

Any one of the following faults will trip all supplies:

- Pulse duration - Trip Power Supplies (PS) if there is a presence of COIL current at a level (adjustable) for more than an adjustable duration of time - this is established by looking at the current;
- Pulse interval - Trip the power supplies if more than one pulse is imposed before an adjustable waiting period.) - this is also established by looking at the current; and
- PLC faulted
- Coil cooling system fault;
- Test Cell - loss of door interlocks
- Loss of E-Stop permissive
- All Power supplies in remote mode fault
- Test Cell door interlock fault
- PLC interface computer fault
- E-stop fault
- Power supply duty cycle interlock fault

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5.1.4 Individual Power Supply Enable Permissive Protection

These trips will only trip the affected supply:

- Summed permissive from power supply trip;
- No ground fault on power loop trip;
- 4160 KV breakers trip;

5.1.5 Pulse Duration & Period Timer Protection

If the pulse duration is more than an adjustable setting, the permissive to the supplies will be removed. This is based on a Start of Pulse (SOP) command received, and **WITHOUT** looking at the current.

5.1.6 Pulse Interval Protection

If the pulse **INTERVAL** is more than an adjustable setting, the permissive to the supplies will be removed. This is based on a Start of Pulse (SOP) command received, and **WITHOUT** looking at the current.

5.1.7 Ground Fault Protection

Coil Ground fault detection and protection will be provided for all circuits. One common Ground Fault relay will be used.

6.0 FACILITY PREPARATIONS

The following preparations are required prior to energizing any single or multiple coil system:

- Machine area scrubs complete;
- Work permits reviewed and closed out as appropriate;
- Installation procedure run copies reviewed and closed out as appropriate;
- Status of temporary modifications to NCSX operating equipment reviewed;
- Bus/coil/power systems walk down complete
- C-Site ECS CSIS, HIS, HCS interlock testing complete;
- C-Site ECS system kirk interlock testing complete;
- Testing of the Central Safety Interlock System (CSIS) with areas safe for access complete;

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- C-Site Lockout Device testing complete;
- Emergency Stop system testing complete;
- Testing of the Hot Access and HIS systems with C-Site safing device activated.

7.0 VACUUM VESSEL PUMPDOWN AND TESTING

The integrity of the vacuum system will be confirmed prior to the introduction of gas for first plasma and shall include the following preparatory steps:

- Preliminary vacuum vessel high-pots successfully completed;
- Preparations for NCSX pump down complete; and
- Vacuum vessel pump down complete.

8.0 E-BEAM MAPPING/TESTING

E-Beam Mapping and Testing will be performed under the controls of NCSX - ISTP-(TBD)-001. During E-beam mapping and testing current to the coil system will not exceed 10 % of the full rated capacity of the coil. In addition only single coil testing (no combined fields) will be performed during this testing phase.

9.0 C-SITE ENERGY CONVERSION SYSTEMS TESTING

The following tests shall be performed prior to energizing any C-Site energy conversion systems for startup:

- C-Site rectifier settings checked;
- C-Site SDS pre-operational testing complete;
- C-Site ECS HCS input/output interface testing complete;
- C-Site ECS interlock and display testing complete;
- C-Site shunt systems PTPs complete;
- C-Site ECS continuity, resistance, inductance, and meggar measurements complete;
- C-Site ECS ground fault detector testing complete;
- C-Site ECS high pot testing complete;
- C-Site Simulation and I/O testing complete;

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- C-Site Dummy load testing complete;
- C-Site Coil Protection Devices.

10.0 PREPARATIONS FOR COIL ENERGIZATION

The following tests shall be performed prior to coil energization:

- NCSX prepared for operations per the daily start-up procedure;
- NCSX prepared for high power pulsing (HPP) operations;
- Coil and bus system high pot and circuit resistance measurements from the SDS output complete;
- C-Site ECS start up and high pot of the NCSX coil systems complete; and
- Pre-operational testing of coil systems complete.

11.0 COIL ENERGIZATION TESTING

All of the activities identified in Sections 9.0 and Section 10.0 must be completed prior to the commencement of coil energization testing for first plasma. Coil energy tests complete. All personnel safety controls (Section 4.0) must be appropriately configured (i.e., safety loop set).

12.0 CRYOSTAT OPERATIONAL

Prior to declaring the cryostat operational, the following preparatory steps must have been completed:

- Cryostat testing complete;
- Cryostat (loss of coolant) alarm and system shut down test complete;
- Cryostat filled and operational.

13.0 CSIS AND ACS TESTING

The operation of the Central Safety and Interlock System and the Access Control System will be confirmed prior to energizing any single or multiple coil system. This shall include the following:

- CSIS/ACS Preoperational Test complete;
- Testing of the E-Stops (similar to an NSTX procedure, annual) testing complete;

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- Operation of the NCSX CSIS.

14.0 APPROVAL FOR COIL ENERGIZATION & FIRST PLASMA

The coil energization tests represent the first time the coils have been subject to design-level currents and voltages in situ and the first time there has been the potential for plasma formation with the associated radiation hazards. Safety Certificate approvals are required for e-beam mapping, normal coil energy testing. The Safety Certificate may impose limits on certain parameters that constitute conditions for the authorized operations.

14.1 Coil Energization Approval Requirements

Prior to coil energization testing, a Safety Certificate for (limited) operation must be issued. The Safety Certificate is issued at the end of construction after the Activity Certification Committee (ACC) has made appropriate presentation and recommendation to the PPPL ES&H Executive Board for the safe start up and operation of the device.

14.2 First Plasma Approval Requirements

The following reviews and approvals will need to occur prior to First Plasma:

- SRC review and approval of NCSX SAD;
- Review and approval of technical documents in of this plan;
- Operational Readiness Assessment Review (ORA);
- ACC review and walk-down of NCSX subsystems;
- Approval by ES&H Executive Board for issuance of Safety Certificate;
- Concurrence from the Test Director, NCSX Chief Operating Engineer, and ACC that all subsystem PTP's (for First Plasma) have been successfully completed; and
- Approval by the NCSX Project Manager to commence First Plasma.

15.0 FINAL CONDITIONS

All above conditions have been successfully implemented in support of the commencement of the full ISTP and first plasma.