Princeton Plasma Physics Laboratory **NSTX Machine Proposal**		
Title: **RWM mode ID & feedback control algorithm testing**		
OP-XMP-045	Revision: **3**	Effective Date: February 9, 2006 *(Ref. OP-AD-97)* Expiration Date: February 9,,, 2008 *(2 yrs. unless otherwise stipulated)*

Procedure Approvals	
Responsible author: **A. Sontag**	Date
ATI (NSTX Physics Ops):	Date
RLM (NSTX Experimental Research Ops):	Date

Responsible Division: **Experimental Research Operations**

Procedure Requirements
designated by RLM

n/a	NSTX Work Permit (TBD)	**n/a**	Lockout/Tagout (OP-AD-61)
n/a	TFTR Work Permit (OP-AD-09)	**n/a**	Door Permit (OP-G-93)
n/a	Tritium Work Permit (OP-AD-49)	**n/a**	T-MOD (OP-AD-03)
n/a	RWP (HP-OP-20)	**n/a**	Lift Procedure (ENG-021)
n/a	Confined Space Permit	**n/a**	DCA/DCN (OP-AD-104)
n/a	Pre-job brief (OP-AD-79)	**n/a**	ATI Walkdown
n/a	USQD (OP-AD-63)	**n/a**	Independent Review
n/a	Master Equip. List Mod (OP-AD-112)	**n/a**	ES&H Review (NEPA, IH, etc)

MINOR MODIFICATIONS

REVIEWERS (designated by RLM)		
Role	**Name**	**Initial/Date**
ATI		
Test Director		
Independent Reviewer		
D-Site Shift Supervisor		
NSTX		
TFTR Caretaking		
Vacuum		
Computer		
Tritium		
QA/QC		
AC Power		
FED		
ECS/MG		
FED		
ERWM		
Water		
NB		
RF		
Diagnostics		

TRAINING (designated by RLM)			
Training required: No ■ Yes ☐ Instructor _____			
Personnel (group, job title or individual name)	Read Only	Instruction	Hands-On
Training Rep. _____			

RLM _____

NSTX MACHINE PROPOSAL

TITLE: **RWM mode ID & feedback control algorithm testing** No. **OP-XMP-045**

AUTHORS: **A. Sontag** DATE: **February 9, 2006**

---

1. Overview of experiment:

This experiment will test the real-time RWM n=1 mode identification and active control algorithms in the PCS. This work will provide the practical basis for later RWM active mode control experiments.

Specifically, this experiment will examine:

1) accuracy of real-time n=1 mode identification results as compared to post-processed mode identification, and use of baseline re-zeroing

2) routine latency and proper data archival

3) most appropriate sensor array(s) to provide input for feedback control

4) requested output to SPAs in response to measured n=1 perturbations in combination with pre-programmed SPA currents

5) maximum stable gain for feedback control system

2. Justification:

Active mode control using the error field correction coil set has not previously been attempted on NSTX. There are many issues, as outlined above, which need to be addressed to ensure this system is capable of performing feedback control experiments. This test will ensure that run time allotted to feedback control experiments is not wasted debugging control system software.

3. Plan:

The mode ID algorithm will be tested first by allowing this routine to run in the background during vacuum testing and calibration shots and first attempts at plasma. No specific plasma conditions are required, so this should be run at the earliest date when the feedback and control systems are operational. This routine will be run in three configurations to test the appropriateness of using either the upper or lower sensor array independently or an average of the two arrays for mode identification. For each of the three cases, the following checks should be made:

1. the output amplitude and phase angle signals will be examined to ensure that they are being archived properly
2. the latency for the mode ID process will be examined to make sure it is acceptable for control purposes ($t_{latency} < 0.5$ ms)
3. the determined amplitude and phase angle will be compared with the results of the post-processed routine using the same subset of sensor compensation
4. the baseline re-zeroing will be examined to check if the results are providing an appropriate mode amplitude for feedback control

The computed mode ID signals from the upper and lower arrays should be compared to the mode ID signals from the average for PF only vacuum shots. This will indicate the effectiveness of averaging in removing the m=0 component of the error field.

The feedback control routine will be tested in stages which will allow testing of most system functions in piggy-back mode with the SPA switches open, but will require some dedicated shots to test the entire system with the SPAs powering the coils.

Initial tests with the SPA switches open will test the following:

1. the ability of the feedback algorithm to read the mode amplitude and phase angle from the mode ID algorithm
2. the archiving of the SPA current requests
3. latency of routine with amplitude threshold switch on and off

   ⇒ this switch may be unnecessary if baseline re-zeroing is effective
4. requested SPA currents in the case of pre-programmed coil currents only with zero feedback gain
5. requested SPA currents with non-zero gain, constant phase angle, but zero pre-programmed SPA currents

   ⇒ ramp feedback gain to determine what gain level causes the power supply request to saturate
6. requested SPA currents with non-zero gain, varying phase angle, and non-zero pre-programmed SPA currents

Once the previous testing is successful, the SPAs will be added to test the full feedback system. Tests with the full system can initially take place in vacuum to determine the system response with the real and imperfect sensor compensation, but without complications due to plasma effects. Repeat a vacuum shot starting with a gain of 10% the value that causes power supply saturation as determined in step 5 above and a fixed phase angle of 180°. Step the gain up from shot to shot until the system becomes unstable. Next, repeat this testing with a plasma shot rather than a vacuum shot. The gain should start at 20% of the value which causes saturation in vacuum.

The latency tests need to determine both the latency of the control system in sending current requests to the power supplies based on input from the sensors, and the latency of the power supplies in responding to these current requests. It is the total latency of this system that will determine the effectiveness of this mode control scheme. The power supply latency can be determined during magnetics calibration shots by determining the time delay between the archived current requests and the measured coil currents.

Run Plan

NOTE: Many of these shots will be taken for other purposes (magnetics calibrations, ISTP, etc.) and the appropriate data taken in piggy-back mode.

A. PF #5 only mode ID algorithm testing shots – upper array, lower array, and average

_____

Test Director

PF #5 only upper sensor array

_____ _____

Shot number Test Director

PF #5 only lower sensor array

_____ _____

Shot number Test Director

PF #5 only upper and lower average

_____ _____

Shot number Test Director

B. Fiducial plasma mode ID algorithm testing shots – upper array, lower array, and average

_____

Test Director

fiducial plasma upper sensor array

_____ _____

Shot number Test Director

fiducial plasma lower sensor array

_____ _____

Shot number Test Director

fiducial plasma upper and lower average

_____ _____

Shot number Test Director

C. Feedback control testing – SPA switches open – fiducial plasma shots

_____

Test Director

pre-programmed currents only (waveform #1), zero feedback gain

_____ _____

Shot number Test Director

ramp feedback gain (ramp gain from zero to 10 over time window from t_{start} to t_{end}), phase angle 180°, zero pre-programmed current

_____ _____ _____ _____

t_{start} t_{end} Shot number Test Director

step feedback gain (step gain from zero to max. non-saturation gain during time window from t_{start} to t_{end}), phase angle 180°, zero pre-programmed current

_____ _____ _____ _____

t_{start} t_{end} Shot number Test Director

step feedback gain (step gain from zero to max. non-saturation gain during time window from t_{start} to t_{end}), ramp phase angle (ramp phase angle from 0° to 180° during time window), zero pre-programmed current

_____ _____ _____ _____

t_{start} t_{end} Shot number Test Director

step feedback gain (step gain from zero to max. non-saturation gain during time window from t_{start} to t_{end}), phase angle 180°, waveform #1 pre-programmed current with n=3 SPA amplitudes

_____ _____ _____ _____

t_{start} t_{end} Shot number Test Director

D. Feedback control testing – SPA switches closed –vacuum shots with fiducial plasma waveforms

_____

Test Director

Step feedback gain: Step gain from zero to max. non-saturation gain using 3 steps of 1/3 max amplitude/step with a 50 ms step width, phase angle 180°, zero pre-programmed current . Step to G_1 at t_1, G_2 at t_2, and G_3 at t_3. Go to zero gain at t_3 + 50 ms.

_____ _____ _____

G_1 G_2 G_3

_____ _____ _____

t_1 t_2 t_3

_____ _____

Shot number Test Director

if unstable oscillations observed in previous shot:

Step feedback gain from highest stable value above to unstable value in three equal amplitude 50 ms steps, phase angle 180°, zero pre-programmed current.

_____ _____ _____

G_1 G_2 G_3

_____ _____ _____

t_1 t_2 t_3

_____ _____

Shot number Test Director

Step feedback gain from zero to G_1 during time window and add n=3 pre-programmed current in three 50 ms steps (waveform #1), phase angle 180°.

_____

G_1

_____ _____

t_1 t_2

_____ _____

Shot number Test Director

E. Feedback control testing – SPA switches closed –fiducial plasma shots

_____

Test Director

Step feedback gain: Step gain from zero to max. non-saturation gain using 3 steps of 1/3 max amplitude/step with a 50 ms step width, phase angle 180°, zero pre-programmed current . Step to G_1 at t_1, G_2 at t_2, and G_3 at t_3. Go to zero gain at t_3 + 50 ms.

_____ _____ _____

G_1 G_2 G_3

_____ _____ _____

t_1 t_2 t_3

_____ _____

Shot number Test Director

if unstable oscillations observed in previous shot:

Step feedback gain from highest stable value above to unstable value in three equal amplitude 50 ms steps, phase angle 180°, zero pre-programmed current.

_____ _____ _____

G_1 G_2 G_3

_____ _____ _____

t_1 t_2 t_3

_____ _____

Shot number Test Director

Step feedback gain from zero to G_1 during time window and add n=3 pre-programmed current in three 50 ms steps (waveform #1), phase angle 180°.

_____

G_1

_____ _____

t_1 t_2

_____ _____

Shot number Test Director

4. Required machine, beam, ICRF and diagnostic capabilities:

The ISTP for commissioning the SPA/EFC coil set must be completed prior to running this XMP. EFC coil set configured for odd-n field generation (diametrically opposing coils connected in same sense about their joining axis). Internal RWM sensor arrays calibrated.

_____

Test Director

5. Sign-off and Documentation

5.1 Permission to Proceed:

_____

Head, Experimental Research Operations Division

5.2 Documentation of results:

Documentation of the results completed, attached to proposal and sent to Ops. Center with copies to Cognizant Physicist and Head of Boundary Physics.

_____

Test Director

PHYSICS OPERATIONS REQUEST

OP-XMP-045

The only specific operations requests are for SPA currents. An n=3 field structure is desired, so the waveform below is appropriate for SPA #1 & #3. SPA #2 will have a similar waveform with the amplitude inverted.

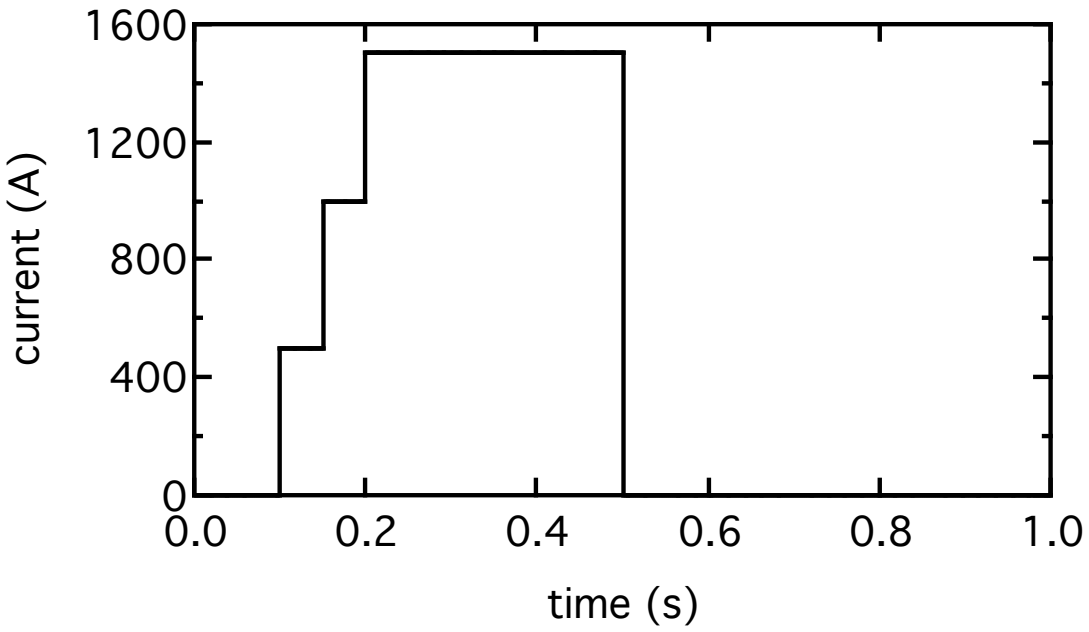
Waveform #1: Stepped square wave – timing may be adjusted based on operating conditions

step to 500 A at 0.1 s

step to 1000 A at 0.15 s

step to 1500 A at 0.2 s

hold at 1500 A until 0.5 s



The PF #5 waveform for the PF #5 only shots is to be taken from the magnetics calibration shots. The vacuum shots and fiducial plasma shots will use the coil waveforms developed during the attempts at first plasma.

DIAGNOSTIC CHECKLIST

OP-XMP-045

Diagnostic	Need	Desire	Instructions
Bolometer – tangential array			
Bolometer array - divertor			
CHERS			
Divertor fast camera			
Dust detector			
EBW radiometers			
Edge pressure gauges			
Edge rotation spectroscopy			
Fast lost ion probes - IFLIP			
Fast lost ion probes - SFLIP			
Filterscopes			
FIReTIP			
Gas puff imaging			
H_a camera - 1D			
Infrared cameras			
Interferometer - 1 mm			
Langmuir probe array			
Magnetics – Diamagnetism			
Magnetics - Flux loops		✓	
Magnetics - Locked modes	✓		
Magnetics - Pickup coils	✓	✓	
Magnetics - Rogowski coils		✓	
Magnetics - RWM sensors	✓		
Mirnov coils – high frequency		✓	
Mirnov coils – poloidal array		✓	
Mirnov coils – toroidal array		✓	
MSE			
Neutral particle analyzer			
Neutron measurements			
Plasma TV			
Reciprocating probe			
Reflectometer – core			
Reflectometer - SOL			
RF antenna camera			
RF antenna probe			
SPRED			
Thomson scattering			
Ultrasoft X-ray arrays			
Ultrasoft X-ray arrays – bicolor			
Visible bremsstrahlung det.			
Visible spectrometer (VIPS)			
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray fast pinhole camera			