NSTX-U Massive Gas Injector Final Design Review

February 18, 2016

Massive Gas Injection Final Design Review

- Purpose of the Massive Gas Injection (MGI)
- Valve Hardware Summary
- Prior chit summaries and resolutions
- Schematics and drawings of electrical system(s)
  - Grounding
  - Interlocks
  - Circuit protection
- Testing, Installation Procedures and Access Procedures
- Operating procedure
- Summary

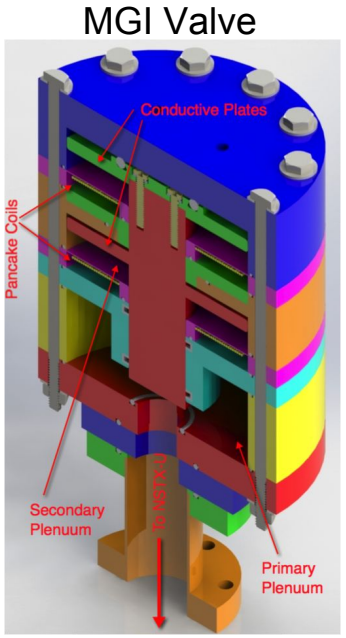
What is the purpose of the MGI?

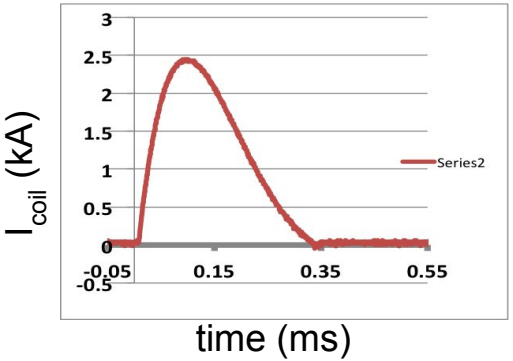
- Tokamak discharges often terminate with a disruption. Unless detected and prevented, these can create deposit large amounts of electrical and thermal energy into the surrounding mechanical structure.
  - Cause excessive divertor heat loads
  - Generate large halo currents
- Injecting massive amounts of gas prior to the disruption can thermally quench the plasma and reduce the impact of disruptions.
- NSTX-U is studying the effects of MGI at various poloidal locations around the plasma.
- The injector design installation has been reviewed earlier; Power supplies and control systems for valve operation are presented here.

- This is NOT a human- or machine- protection system; It is a diagnostic on NSTX-U.

MGI Valve Hardware

- 2 plenums
  - Primary/Lower (200 psig, 1000 Torr)
  - Secondary/Upper (100 psig, 5000 Tor)
- Aluminum conductive plates connected to piston
- Coil inside of valve body will be momentarily injected with several (1-2.5) kA of current for less than 0.5 ms
- Eddy currents in plates will force the valve to open; Gas will rapidly flow out of valve, down a pipe to the NSTX-U plasma
- Gas quenches plasma
  - How does the the location at which the gas is injected affect the behavior of the plasma quench?
  - Experiments on NSTX-U will help in understanding this





Prior Chit Summaries, CDR (1/3)

Item	Concern/Recommendation	Current Status
1	For during-shot digitized signals, the A/D trigger time and the data sampling time must be correlated. Or, also digitize a 3rd "timing mark" channel.	**A T=0 fiducial trigger will be digitized and recorded to MDSplus.**
2	Define EPICS interface: Stored settings, Waveforms, Shot #, etc.	Plan to record charging request, charge timings, and digitized shot data
3	Battery status needs monitoring. Replace with power supply	Administratively changed every run campaign.
4	At end of charging, ensure that disabling high voltage does not short the Glassman Supply output.	Delay added between relay connection break and HV turn off.
5	The Ip Calculator has an "ITF < allowable" signal. Assess of this should be incorporated into the MGI Controls	**PCS will handle the check to verify that the toroidal current is within the acceptable range.**
6	On the "NI Chassis V20151014a"inputs; Check the interface for "Loop Set/HIS". Contact closure or 120VAC?	120 VAC – SSR added to circuit

Prior Chit Summaries, CDR (2/3)

Item	Concern/Recommendation	Current Status
7	24 V supply to control logic rather than 10V (as shown)	24 V will be used
8	Do not co-mingle the High Voltage and A/C Control power in Box #2	To be verified on delivery & installation.
9	On the Power Supply drawing, show I/O Voltages. Also correct the drawing to remove the wire in parallel with R8 (110 ohm)	Done (see below)
10	Make a "grounding" diagram for the next review. Should show ground classes and locations of electrical breaks	Done (see below)
11	Confirm that the gas delivery system P&ID's have been updated to show the MGI configuration.	Plumbing is done. Instrumentation may not be done.
12	Develop the plan/requirements for electrical insulation tests (Hi-Pots) when the system is installed. This will help determinewhere to ensure that sufficient insulation exists.	Will follow CHI template

Prior Chit Summaries, CDR (3/3)

Item	Concern/Recommendation	Current Status
13	Work packages for system interfaces in the NTC should be prepared/released as soon as possible	CAD underway. Interfaces between Vacuum PLC, EPICS, PCS, MDSplus, AC power, Interlock systems have been identified/defined. Installation Procedure (IP) to follow shortly.
14	The MGI capacitor discharge system meets the criteria of a Cap Bank as described in the PPPL Health and Safety Manual. Needs to meet specific safety requirements. (Access procedure, etc.)	Safing and access procedures to follow CHI as a template. Frank Hoffman is taking the lead on the Access Procedure (AP).
15	Recommend development of an access procedure outlining a safe and practical process for safing all parts of the system. Needs to include interlocks, required PPE, visibility of conditions, discharge and grounding sticks, rtc.	

Prior Chit Summaries, PDR (1/2)

Item	Concern/Recommendation	Current Status
1	Consider a future software functional review, which includes a written document describing the software functions, interlocks, FMEA, and EPICS communication.	Software design review completed on 2/10/2016.
2	Interfaces with the Plasma Current Calculator need to be finalized.	Ip calculator will not be used. PCS will be the system that inhibits the MGI from firing if the toroidal field current is out-of-range.
3	Make sure that there is a cog. Engineer who is responsible for completion of electrical installation procedures and drawings, and ensuring that electrical installation work is executed. The electrical cog. Engineer needs to work closely with the mechanical cog. engineer to insure that the proper connections are made to the valves and a suitable integrated system test procedure (ISTP) is formulated	That's me. I will be handing stuff off to F. Hoffman over the next few weeks/months as this project reaches its experimental goals.

Prior Chit Summaries, PDR (2/2)

Item	Concern/Recommendation	Current Status
4	Ensure that TIV control and interlocks are scheduled for implementation by the MGI need date.	Mark Cropper has confirmed that this will be completed by the need date.
5	MGI Grounding Diagrams need to be reviewed/approved by the PPPL Grounding Engineer. Similarly all installation/access procedures need to be reviewed by the PPPL Electrical Safety Specialist	Diagrams (in current state) have been reviewed. Will repeat the reviewed again once completed. IP and AP will be reviewed by appropriate personnel.
6	Provide proper grounding stick and cap bank grounding points	Will be part of access procedure. Grounding method has been discussed with Electrical Safety (G. Anderson) and will be reviewed once finalized.

Prior Chit Summaries, Software DR (1/2)

Item	Concern/Recommendation	Current Status
1	The electrical trigger pulse (generated from an optical signal) should be digitized and recorded. A suitable place is the primary side of the pulse transformer T1.	Will digitize the signal at the primary side of T1.
2	There is no guaranteed pulse length of the incoming trigger signal. The trigger pulse generating circuit does not limit the pulse length and a long pulse could potentially damage the circuit (Q4). The pulse length should be limited, but without changing the turn-on behavior of the trigger circuit (i.e. no false pulse is generated when control power is applied to that circuit).	Will request that the length of the incoming trigger signal is set to minimum. The output transistor (NTE129P) is rated for 1A continuous collector current. Bench tests will be performed to determine to characterize the behavior of the output transistor and its limitations.
3	Sync an internal clock on EPICS shot clock signal at a known time (for example T-60) and use the internal clock for sequencing, rather than relying on non-intermittent shot clock signaling.	Will synchronize with the EPICS shot clock and use internal clock for sequencing.
4	Add recording of aborted shots.	Will record aborted shot status to MDSplus.

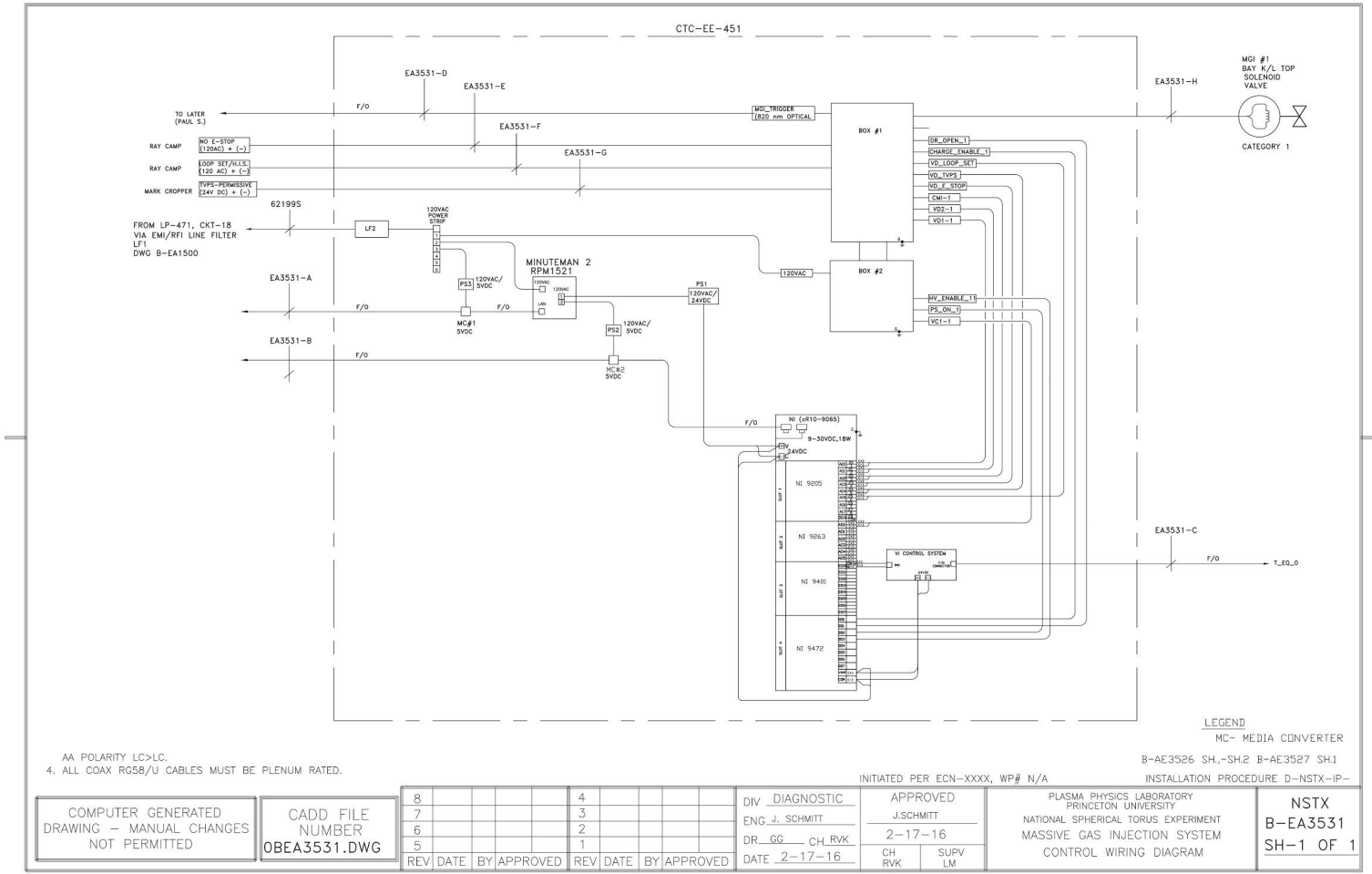
Prior Chit Summaries, Software DR (2/2)

Item	Concern/Recommendation	Current Status
5	Add watchdog to allow transition to safe state if NI VI locks up.	Will consider using NI FPGA watchdog. Safety should be covered by existing interlock/SSR connections. Power cycling NI system is another options.
6	Add a large label with the name of the controlled valve to the GUI of the VI to avoid confusion when multiple GUIs are accessed on one computer via remote connection	MGI controller VI will be labeled to indicate its identity.
7	Add display of MDSPLUS warning to GUI of VI	MDSplus warnings will be displayed on VI.
8	Write all recorded data to the MDSPLUS tree at the end of the shot.	MDSplus data will be written at end of shot (as opposed to prior to the shot).
9	Add a tab for voltage and timing settings, since these will be changed only infrequently and need not be visible on the main screen at all times.	Infrequently used settings will be moved to alternate VI screen (separate tab).

Schematics

See handouts

- Example Rack: ECE-CC-451
- Charging supply box
- Capacitor box
- Grounding diagram



LEGEND

MC- MEDIA CONVERTER

AA POLARITY LC>LC.

4. ALL COAX RG58/U CABLES MUST BE PLENUM RATED.

B-AE3526 SH.,-SH.2 B-AE3527 SH.1

INITIATED PER ECN-XXXX, WP# N/A

INSTALLATION PROCEDURE D-NSTX-IP-

COMPUTER GENERATED DRAWING – MANUAL CHANGES NOT PERMITTED

CADD FILE NUMBER 0BEA3531.DWG

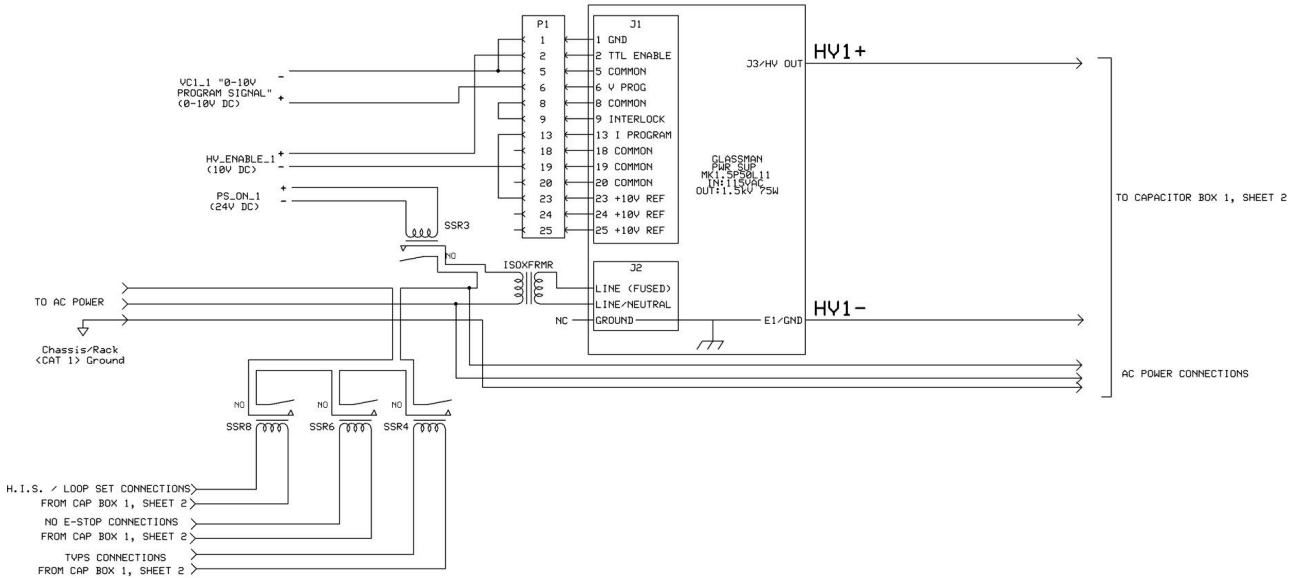
REV	DATE	BY	APPROVED	REV	DATE	BY	APPROVED
8				4			
7				3			
6				2			
5				1			

DIV DIAGNOSTIC
ENG J. SCHMITT
DR GG CH RVK
DATE 2-17-16

APPROVED
J.SCHMITT
2-17-16
CH RVK | SUPV LM

PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT
MASSIVE GAS INJECTION SYSTEM
CONTROL WIRING DIAGRAM

NSTX
B-EA3531
SH-1 OF 1



CADD DWG
ExpressSCH v7.3.1
Filename

REV	ECN	DATE	BY	CHK/APPV

DIV. CODAC DR. JCS

CH. _____ DATE FEB-17-2016

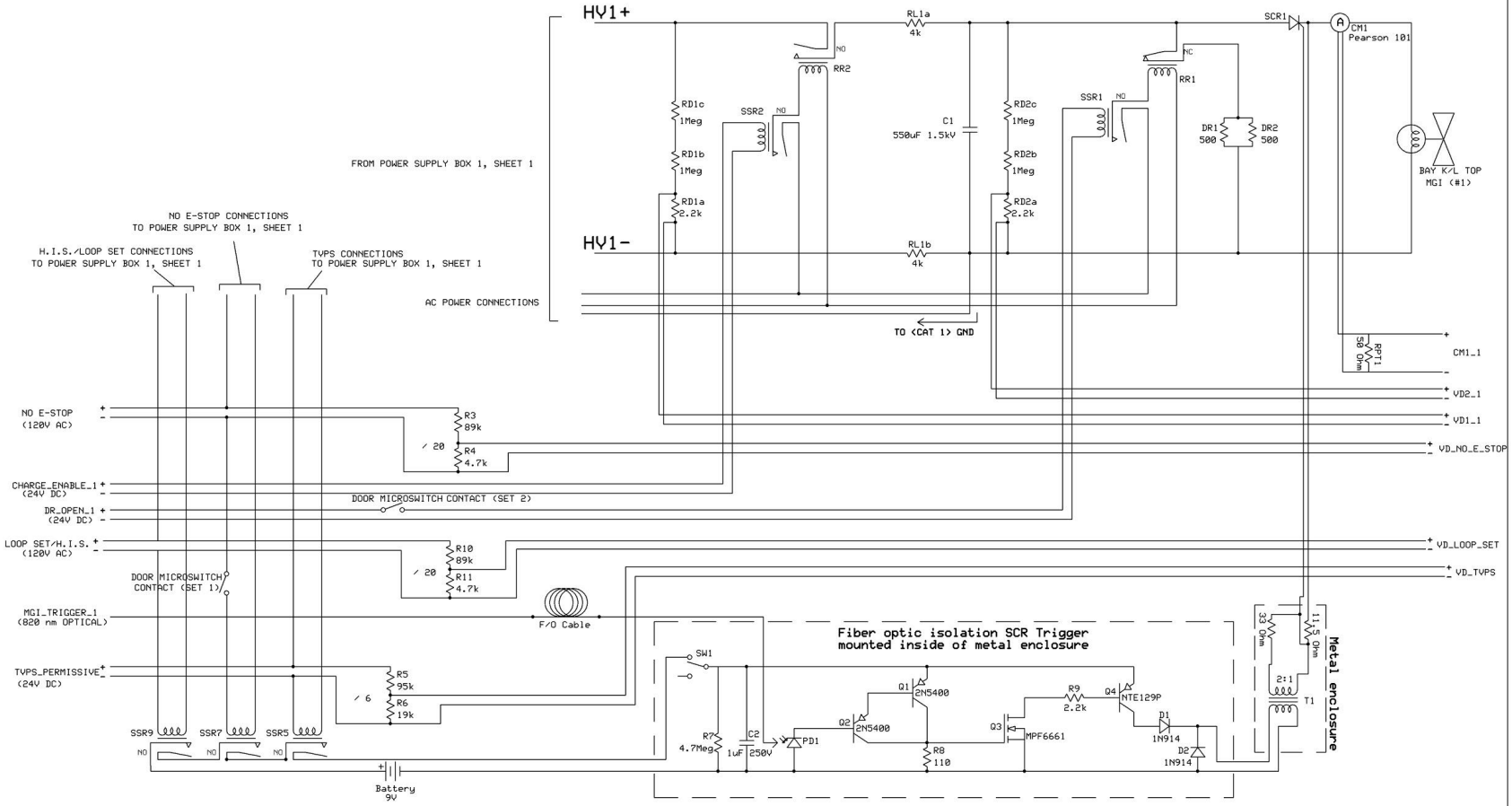
ENGR. J.C. SCHMITT

APPROVED

PRINCETON PLASMA PHYSICS LABORATORY - NSTX-U

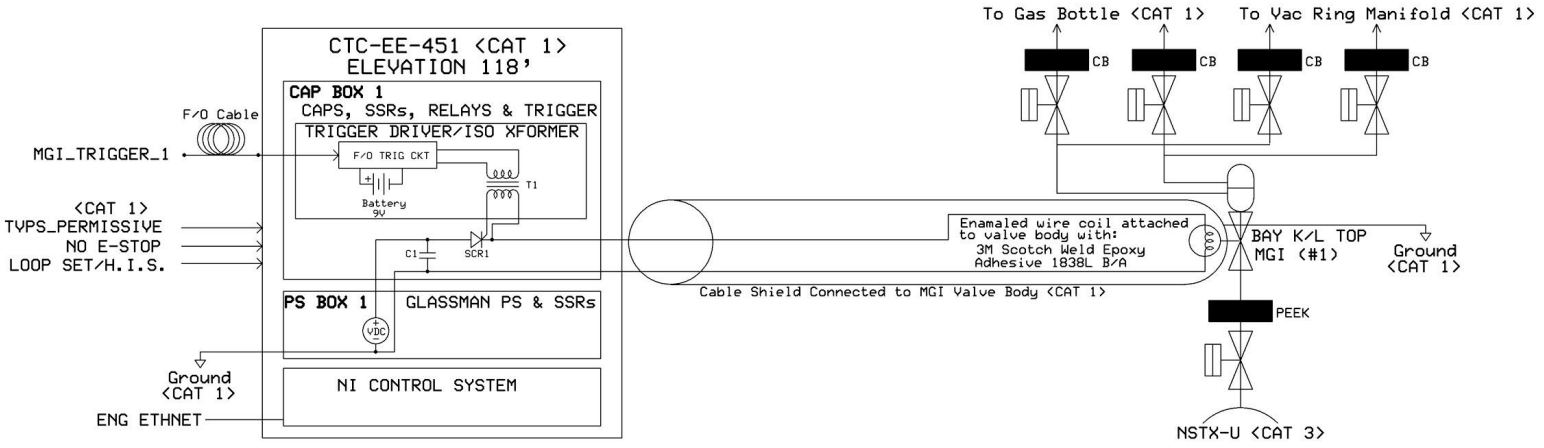
MASSIVE GAS INJECTOR POWER SUPPLY SCHEMATIC DIAGRAM

B-AE3526 Sh 1



					DIV. CODAC DR. JCS	APPROVED	PRINCETON PLASMA PHYSICS LABORATORY - NSTX-U
					CH. DATE FEB-17-2016		MASSIVE GAS INJECTOR POWER SUPPLY SCHEMATIC DIAGRAM
REV	ECN	DATE	BY	CHK/APPV	ENGR. J.C. SCHMITT		B-AE3526 Sh 2

CADD DWG
ExpressSCH v7.3.1
Filename



Ceramic Break (CB) or PEEK

Air Valve

NOTE 1: SEE NSTX E-EA3517 FOR DETAILS OF GAS SYSTEM

CADD DWG	REV	ECN	DATE	BY	CHK/APPV	DIV. CODAC	DR. JCS	APPROVED	PRINCETON PLASMA PHYSICS LABORATORY - NSTX-U	B-AE3528 Sh 2
ExpressSCH v7.3.1						CH.	DATE FEB-17-2016		MASSIVE GAS INJECTOR GROUNDING DIAGRAM	
Filename						ENGR. J.C. SCHMITT				

Interlocks & Circuit Protection

- NO-E-STOP, TVPS_permissive and H.I.S./Loop Set all need to be present for power to be available to Ross relays and the charging supply
  - Without these interlock signals, the capacitor should be shorted through the dump resistors and the power supply should be disconnected from power
  - These signals are also monitored by the Nat. Instr. system which will prevent operation of the charging supply and Ross relays

- Transient Voltage Suppression (TVS) diodes are installed on the analog input lines of the Nat. Inst. system to protect it from overvoltage spikes

Control System

See https://docs.google.com/presentation/d/1A_pYNHgcMjIiv0hMw2EIBn0cKCjOh4XP3hGC-tvxy88/edit#slide=id.p

Testing, Installation and Access Procedures

- Installation procedures will be completed after drawings are completed.
- Access procedure is in draft. (F. Hoffman)
  - Notes on grounding sticks: The box with the capacitor will have an access ‘slot’ cut into the top to allow grounding stick access
- Testing procedure to be written.

Other Requirements

- NEPA is completed
- Vacuum PLC interface will be completed
- PCS coding will be completed
- Hi-pot tests will be performed as part of IP.

Timeline

See https://docs.google.com/spreadsheets/d/1ZEbJayrZh-BnKS9MQALrjX3z9FwOec4l9gtsaxmiIHM/edit#gid=0

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