This document supplements the NuMI Focusing Horn Power Supply Information Manual , THSR Edition, dated 12-Oct-2004. (NuMI Horn PS Mannual.doc)

NuMI Horn Power Supply semiconductor polarity reversal procedure.

To change the polarity configuration for …Anti-Neutrino Production……
i.e., capacitor bank voltage to be of positive polarity with respect to ground.

Reverse this procedure to reconfigure capacitor bank for Neutrino production

Tools needed: 7/16”, 1/2”, 9/16, 5/8”, 11/16”, 3/4” & 13mm open end/box end hex wrenches,
7/16”, 1/2”, 9/16, & 13mm sockets and wrench
30 lb/ft rated torque wrench
1/4” & 3/8” straight-blade screw drivers,
SAE Allen wrenches
Kim-wipes
Water capable vacuum cleaner

Changes are made within the capacitor bank and the electronic controls. All must be completed before re-energizing the equipment. Utilization of the check-list to assure all steps have been completed is recommend.

Prior to starting reversal procedures of any water cooled semi-conductor assemblies in the capacitor bank, valve off the water Supply and Return lines. These valves, suspended from the ceiling, are located above the capacitor bank enclosure on the side opposite the controls racks.

Next; to drain cooling water from each quadrant’s set of three SCR assemblies, attach a drain hose via the Hansen® disconnects located near the enclosure’s center bay floor. This is most easily accomplished by collecting the drainage water into a plastic bag for ultimate disposal into the sump pit adjacent to the elevator outside of the THSR. It will be beneficial to loosen a fitting at the highest elevation of each quadrant switch panel to allow air entry, facilitating drainage. Inevitable spillage into the enclosure is to be mopped until dry. Any standing water will confuse the leak testing effort to be done before returning the equipment to service. Use ventilating fans if necessary to dry the equipment. In no event energize the system until satisfied all electrical aspects are completely dry.

Note: Any hardware dropped during the reconfiguration process must be recovered and/or accounted for before re-energizing the PEI charging supply to preclude the possible occurrence of a high energy fault either at start-up or at some subsequent time during operation as a consequence of hardware unknowingly bridging conductors.

As a point of information, the capacitor bank operates with its high-side at:
Negative polarity with respect to ground when operating in **Neutrino** mode.
Positive polarity with respect to ground when operating in **Anti-Neutrino** mode.

The following steps are to be followed to complete the reversal process. They can be accomplished in any order with the final step being hydrostatic testing. With multiple personnel they can be performed simultaneously. Estimated time is 10 man-hours.

Output SCRs;

Preface: These are the semiconductors switching stored energy from the capacitor bank into the horns via the stripline. The SCR/heatsinks/clamp package originally designed to prevent mounting of pre-loaded assemblies in the incorrect polarity, now requires auxiliary adapters to accommodate inverse mounting.

Procedure: Remove the water hose connections at the SCR module end of each hose, both input and output. This applies to twelve locations.

Remove the snubber (R-C network) connections, 2 each, from the SCR package. The snubber capacitor and associated components remain in place as is. Set aside the lead attaching hardware for reapplication at completion of the following steps. Be certain lock washers are included.

Using due care, disconnect the gate drive leads to the SCR (Silicone Controlled Rectifier). These terminals/connections are fragile. Any fatal damage to the SCR gate terminals will require removal and replacement with a new device. These are custom made, not off-the-shelf devices. Spares are limited.

Remove the SCR assembly by removing the eight nuts, four above and four below, securing it to the vertical buses. Anticipate lifting a package weight of approximately 15 lbs. (7 kg), having semi-sharp edges/corners and awkward personal positioning during removal. Set aside in a secure location.

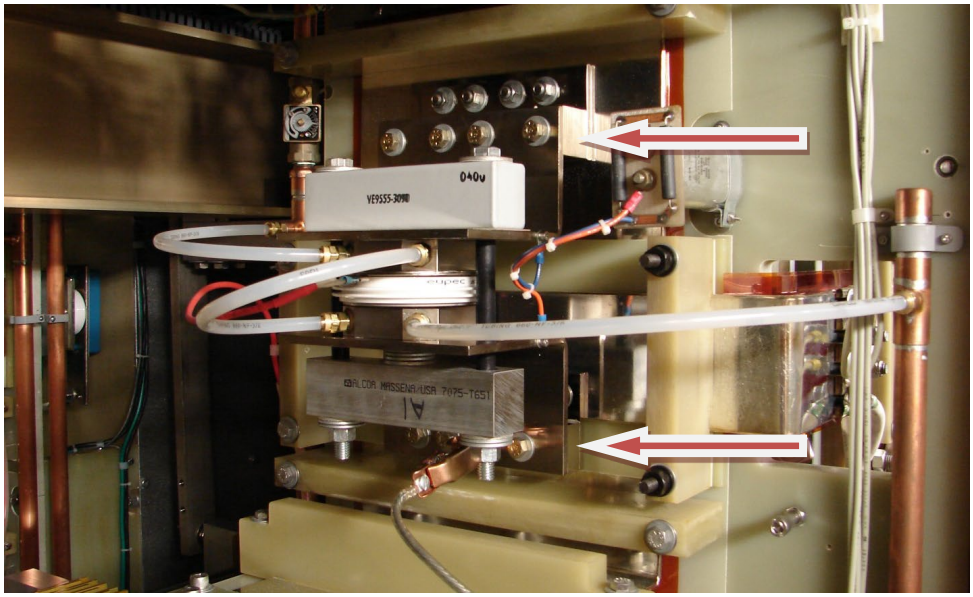


Figure 1. Typical of 12 locations, this SCR package is shown mounted in the inverse, or Anti-Neutrino polarity. For inverse operation note that the location identifier-A1-is also in an inverse orientation.

A top and bottom adapter, marked by arrows in Figure 1, are next installed at each mounting location to accommodate inverse mounting of the SCR package. The bolt patterns for the adapters are of two different arrangements. Each SCR location will require one of each. The preferred method of assembly is to attach the adapters first to the stationary bus followed by the mounting of the SCR package to the secured adapters. Be certain a sparing amount of anti-seize compound exists on stainless-to-stainless nut/bolt combinations to prevent galling. All nuts and bolts are to be tightened to 30 lb-ft torque value to assure proven electrical performance.

Re-mount the SCR package. It will install only one way as determined by its mounting hole spacings. *Assembly Tip: Leave the nuts on the upper adapter loose to simplify alignment when mounting the SCR package. The lower adapter must be tightened before hand as nut access will be severely restricted once the SCR package is mounted.* Secure with eight bolts and associated Bellville washers. These are Grade-9 bolts; due not substitute. Tighten to 30 lb-ft by use of a torque wrench to re-establish proven electrical performance.

Re-connect the water hoses, tightening the hex-nut finger-tight. Utilizing a back-up wrench on the stationary portion, tighten the hex-nut an additional 60°, i.e., one flat.

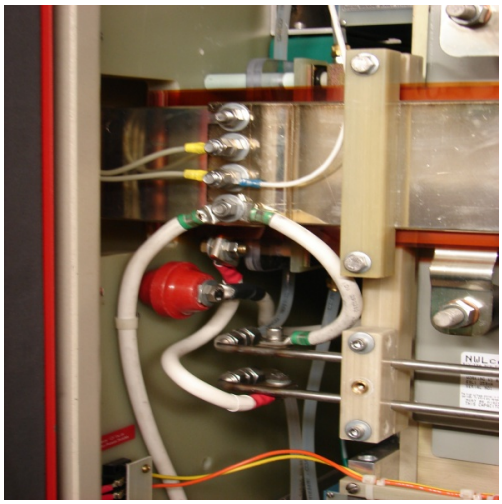
Reattach snubber leads, securing them with the set aside hardware. Be certain a lock washer is included under the screw head. A connection that loosens with time from vibration (opens) could result in the loss of an SCR. Snubber polarity is not significant but attempt to keep all 12 installations the same.

Reconnect the RG-58 co-axial gate drive leads. Proceed carefully! Lateral forces can break the terminal extending from the ceramic, leaving the device useless. Co-ax shield connects to the SCR cathode (bellows) terminal. Co-ax center conductor connects to the terminal extending from the ceramic body of the SCR. Of particular importance when re-connecting the leads is to be sure the gate lead connector is not making short-circuit contact with the cathode bellows of the device. The spacing is close and is inherent with the construction of the device.

Be certain all twelve devices have been reversed. When finished, inspect the gate leads for proper polarity and the gate connector is not inadvertently shorting to the cathode bellows.

Recovery Diodes

Preface: A second set of recovery diodes has been installed in the capacitor bank to facilitate easy polarity reversal, one for each row (cell) of capacitors; twelve locations in all. With this modification, it is only necessary to exchange two leads as identified in Figure 2. They are marked with Red or Black shrink tubing applied to the terminal ends. The active lead will be connected to the terminal of the stainless-steel resistor while the inactive lead will be 'parked' on an insulated stand-off installed for this purpose. Note: The unused lead will be floating at the capacitor-bank voltage during operation so must not be left un-mounted.



Procedure: Exchange the two cable connections between the resistor terminal and the Glastic insulator terminal.

For: Anti-Neutrino operation;
Red on resistor, Black on insulator.

For Neutrino operation;
Black on resistor, Red on insulator.

Figure 2. Anti-Neutrino configuration shown.

All twelve locations must be configured the same way for the respective polarity. If not, a short circuit is presented to the charging PEI supply.

Double check all bolted connections for accuracy, tightness and integrity.

Charge isolation diodes

Preface: The four set-of-three molded-case style diode packages are located in the center bay of the enclosure, mounted on the G-10 structure supporting the stripline. One of these assemblies is shown in Figure 3.

They serve as electrical isolation between each row of capacitors and the single PEI charging source, preventing cap-bank discharge to a faulted PEI or a faulted capacitor in other than the assigned row. In each assembly the common pole of the diodes is connected together by a bus-bar.

Service tip: A loosely captured hex nut is located within the plastic housing of the diodes under each of the copper terminals. Torque loads on this nut during assembly/disassembly tend to jack the nut out of the housing, bending the copper tab up and away from the diode body. This can be

prevented by simultaneously applying a downward force against the diode housing while tightening or loosening the terminal bolts.

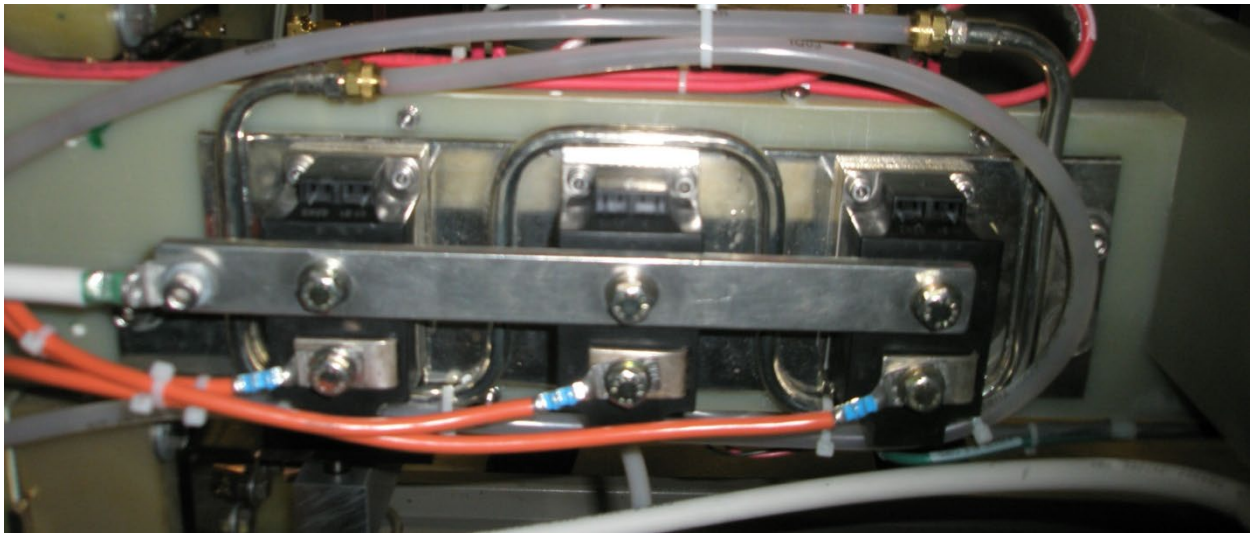


Figure 3.

Procedure: Remove the three individual Orange cables, one from each diode.

Remove the bus-bar from the combination of three diodes and reinstall on the opposite diode pole utilizing the same hardware.

Re-attach the three Orange cables as dictated by lead-length to the remaining pole at each respective diode. Double check all bolted connections, inspecting for tightness and integrity.

Note: Visually inspect the three cable connections to be certain that the cable lugs have not rotated while tightening the bolts such that they can make contact with the bus-bar.

Electronic crowbar

Preface: The electronic crowbar utilizes an SCR as the switching element. Its gate drive circuitry is powered from the capacitor bank voltage. Hence, the electronic crowbar is polarity sensitive. The mechanical crowbar, which it is connected to, is not polarity sensitive. The two crowbars are connected together in parallel, the mechanical units being backup to the electronic unit. All three crowbars are mounted to the ceiling of the center bay of the enclosure.

Procedure: Reverse the two heavy leads connecting the electronic crowbar to the mechanical crowbar contacts. For Anti-neutrino operation the two leads from the electronic crowbar to the mechanical crowbar will be crossed, as shown in Figure 4, depicted by the arrows.

For Neutrino operation, the two leads must be connected such that they are not crossed. Double check both connections, inspecting for accuracy, tightness and integrity.

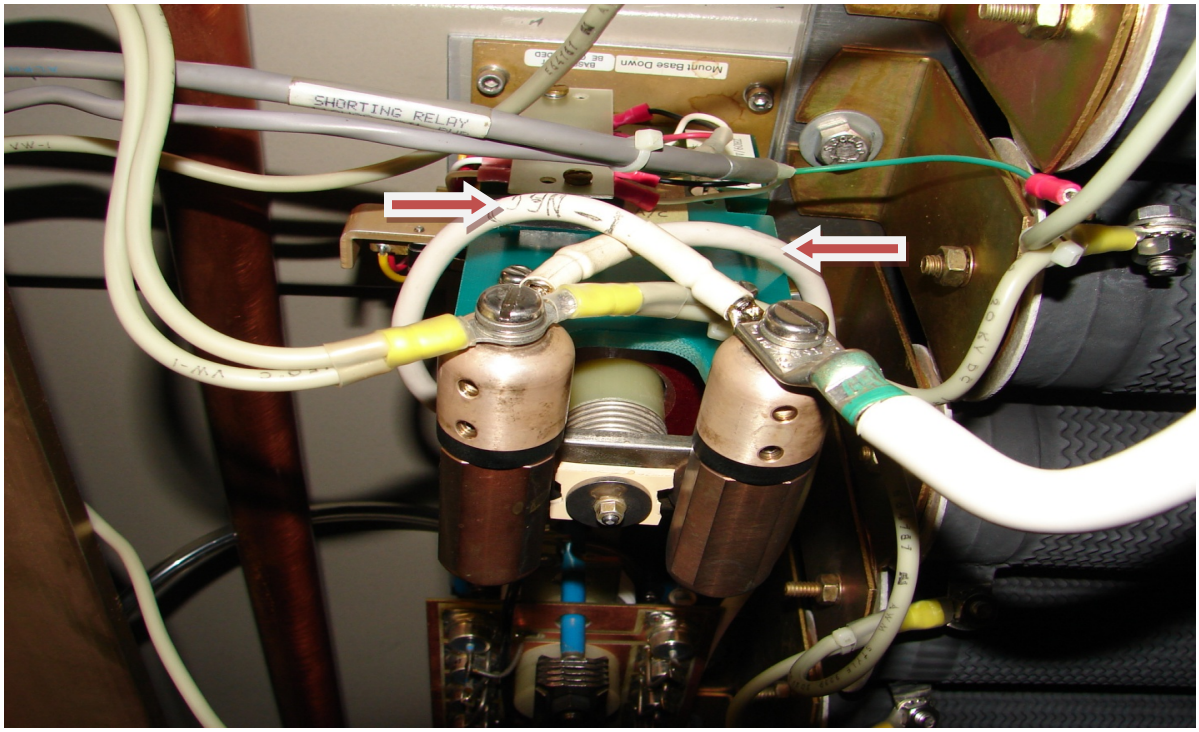


Figure 4. Mechanical crowbar, in foreground, with crossed leads from the electronic crowbar connected to its terminals. The electronic crowbar shown in background, bottom center of image.

PEI Reverse Current Bypass Diode

Preface: This single diode is connected electrically in anti-parallel to the charging source PEI supply to bypass reverse current reflected during a pulse cycle by the inductive horn/stripline load on the capacitor bank. If connected in the forward polarity relative to the charging supply, it will present a short to the PEI. It is physically located and mounted to top of the isolation choke, shown in Figure 5. Ready access is available via the enclosure end doors. *Be cautious of the water cooled resistor assemblies mounted on the face of the choke while working in this location to preclude damaging electrical or water connections to these components.*

Procedure: Interchange the two cables depicted by arrows in Figure 5. Anti-Neutrino configuration shown. Polarities marked on the heatsink are indicative of normal Neutrino-mode connection.

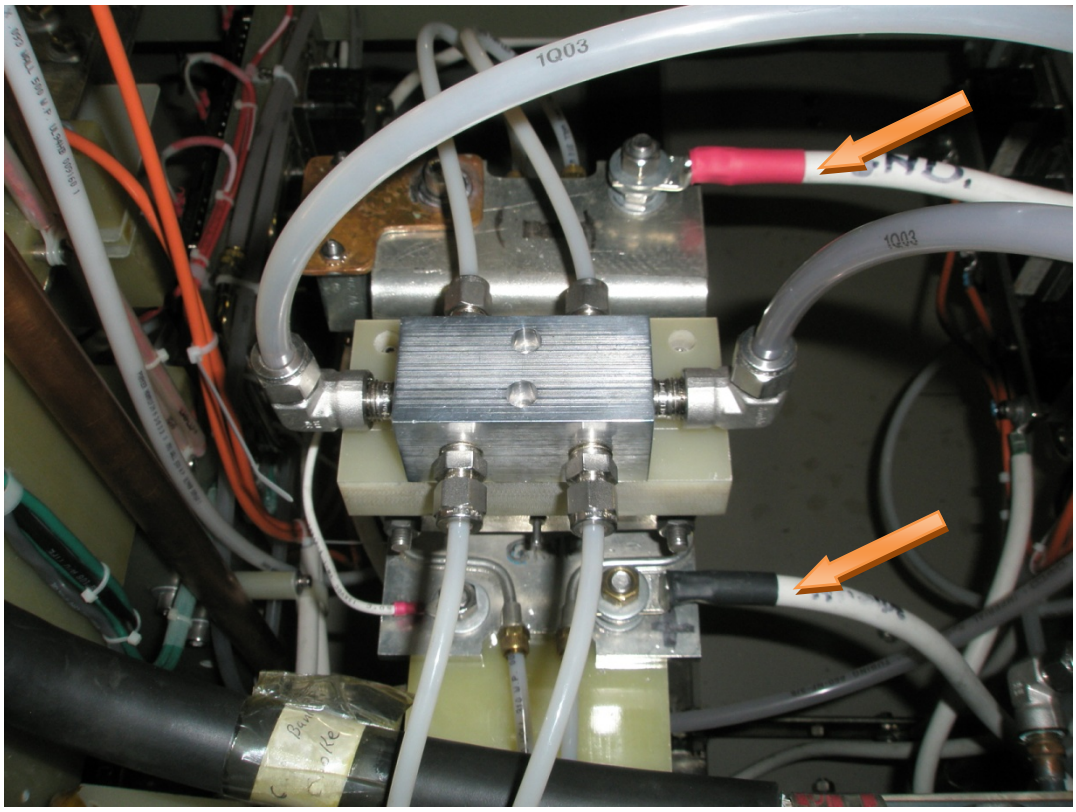


Figure 5. Reverse Current Bypass Diode. Anti-Neutrino configuration shown.

PEI polarity reversal

Preface: The output side of the PEI power supply floats with respect to ground, meaning the supply can operate with either the positive or negative terminal declared ground.

Two PEI supplies are installed in the Target Hall Support Room. One will be active and the other a stand-by spare. Output terminal connections are located on the top panel of the supplies. The cables attaching to the PEI are labeled as to which is ground and which is the hi-side of the capacitor bank.

Note: *The terminal polarities differ from one supply to the other – observe terminal polarity markings when making connections.*

Procedure: For Anti-neutrino operation the capacitor bank operates at positive polarity with respect to ground. Therefore, the 'Capacitor Bank Hi-side' cable shall be connected to Positive PEI terminal. The 'Capacitor Bank Ground' cable is to be connected to the Negative PEI terminal.

For Neutrino operation the capacitor bank operates at negative polarity with respect to ground. Therefore, the 'Capacitor Bank Hi-side' cable shall be connected to the Negative PEI terminal and the 'Capacitor Bank Ground' cable shall be connect to the Positive PEI terminal. Figure 6 shows the top panel of the PEI supply

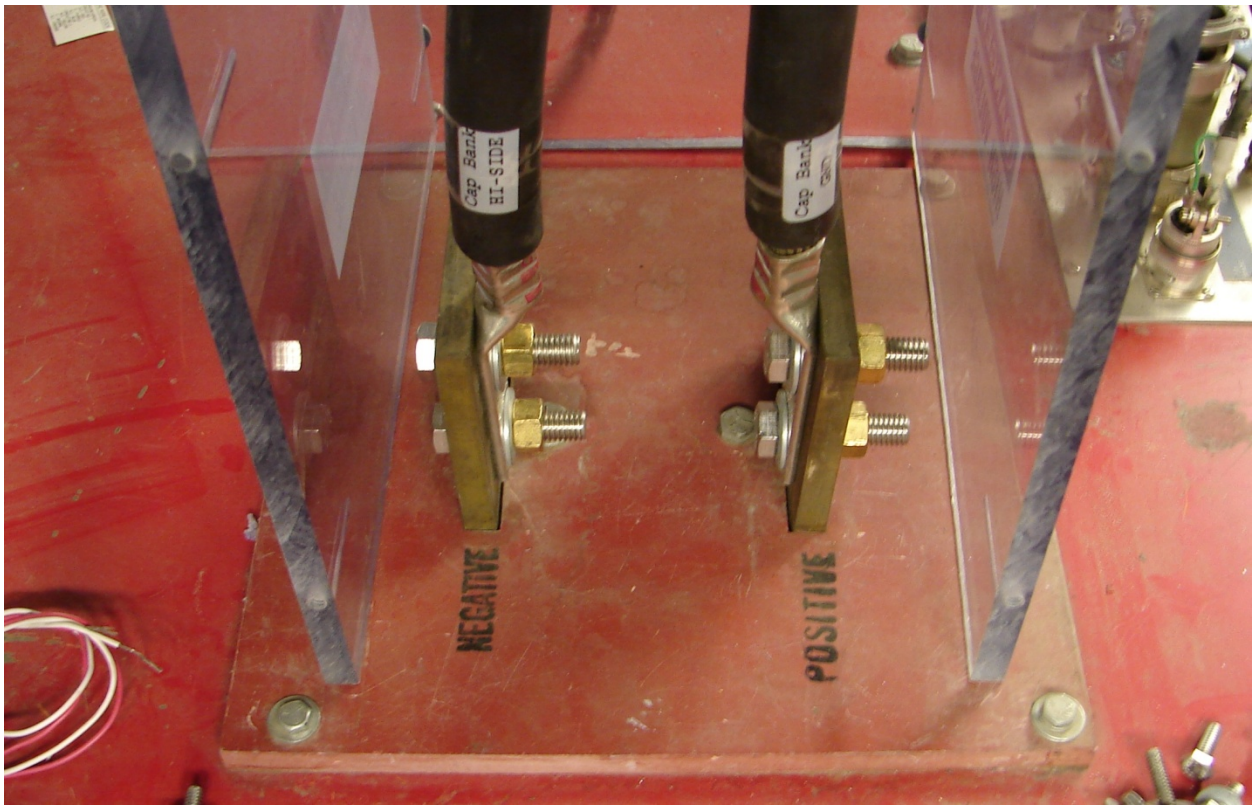


Figure 6. PEI top-panel showing terminals and cable connections. Not labeling of terminals and cables. Connections shown are for Neutrino operations.

Hydrostatic testing:

Preface: With the breaking and re-making of water connections, it will be necessary to hydrostatic test the capacitor bank water cooling loops prior to its return to service. This will reveal any leaks in need of repair and give assurance that the equipment is secure for long term operation. Read through in its entirety and understand this procedure before starting pressure testing. This is a two person procedure.

LCW for this system is supplied by a water skid located on the surface. The capacitor bank will have in addition to the pressure supplied by the skid a head pressure of approximately 60 psi as a result of its location 130 feet below the surface. This is the case for both the supply and return lines.

Note: *All valve operations must be conducted in a gradual manner to avoid high transient pressure spikes, a.k.a. water hammer. The one exception to this; be prepared to close both valves quickly in the event of a substantial spill.*

Procedure: Starting from the condition whereby the water supply and return valves were closed during work activity to reverse the semi-conductors, connect the drain hose to one of the center bay drains via the Hansen fitting, routing the hose to a collection bucket. Open the supply side valve just enough to establish minimal flow. Allow flow to continue until all entrapped air is purged from the respective water circuit, then valve off the supply side water. Repeat this procedure at each of the three remaining center bay drains for the respective water circuits.

With the purge procedure completed, gradually open the return valve to allow the equipment to rise to the return side pressure. This will bring the capacitor bank pressure to approximately 60 psi. Some residual air may still be within the equipment but it will be advantages to check all water connections for leaks in the event a fitting was not initially re-secured.

With the return valve fully open, ever so gradually open the supply side valve until water just begins to flow. Initiation of flow can be determined by observing the passage of trapped air through the equipment hoses and out the return line. Maintain this setting of valves until all air is removed. Again, check all water connections within the capacitor bank for leaks.

Gradually, in increments of 15-20 psi, increase and allowing five or so minutes per step, open the supply valve while watching for water leaks throughout the cooling circuits.

Once water is flowing with both valves fully open, commence the gradual closing of the return side valve. Proceed in incremental steps of pressure, allowing five or so minutes per step while watching for leaks until the return valve is fully closed. At this point close the supply side valve and allow the system to hold pressure for at least ten minutes. This will allow all fittings and hoses in the capacitor bank to rise to the full supply side pressure, approximately 225 psi, and in the event of a leak limit the available water discharge to that which is contained within the capacitor bank. Check all fittings for any leakage.

When satisfied of the system integrity, in sequence – first one valve and then the other, gradually open the supply and return valves to return water flow to normal operation; both valves fully open.

Controls:

A switch located within the "Cell Voltage" Module (9820-EE-370139) must be set for the appropriate polarity of operation. Retaining screws at the four corners of the module must be loosened sufficiently to allow pulling the module forward approximately three inches. Adjust the switch as necessary. It is marked with a 'N' for Neutrino, and an 'A' for Anti-neutrino operation. Once set, re-seat the module and secure by tightening the screws.

On the rear panel of the controls, shown in Figure 7, signal inverting adapters are installed on twelve of the 'ICELL' input channels. Channels 1, 2 and 3; 5, 6,and 7; 9, 10 and 11; 13, 14 and 15, as indicated by the red arrows in Figure 7, receive the adapters.
'ICELL' input channels 4, 8, 12, and 16 are not used in the NuMI horn system.

These adapters are only used for Anti-neutrino operation. When not in use, they are stored in the drawer located just below the controls rack oscilloscope.

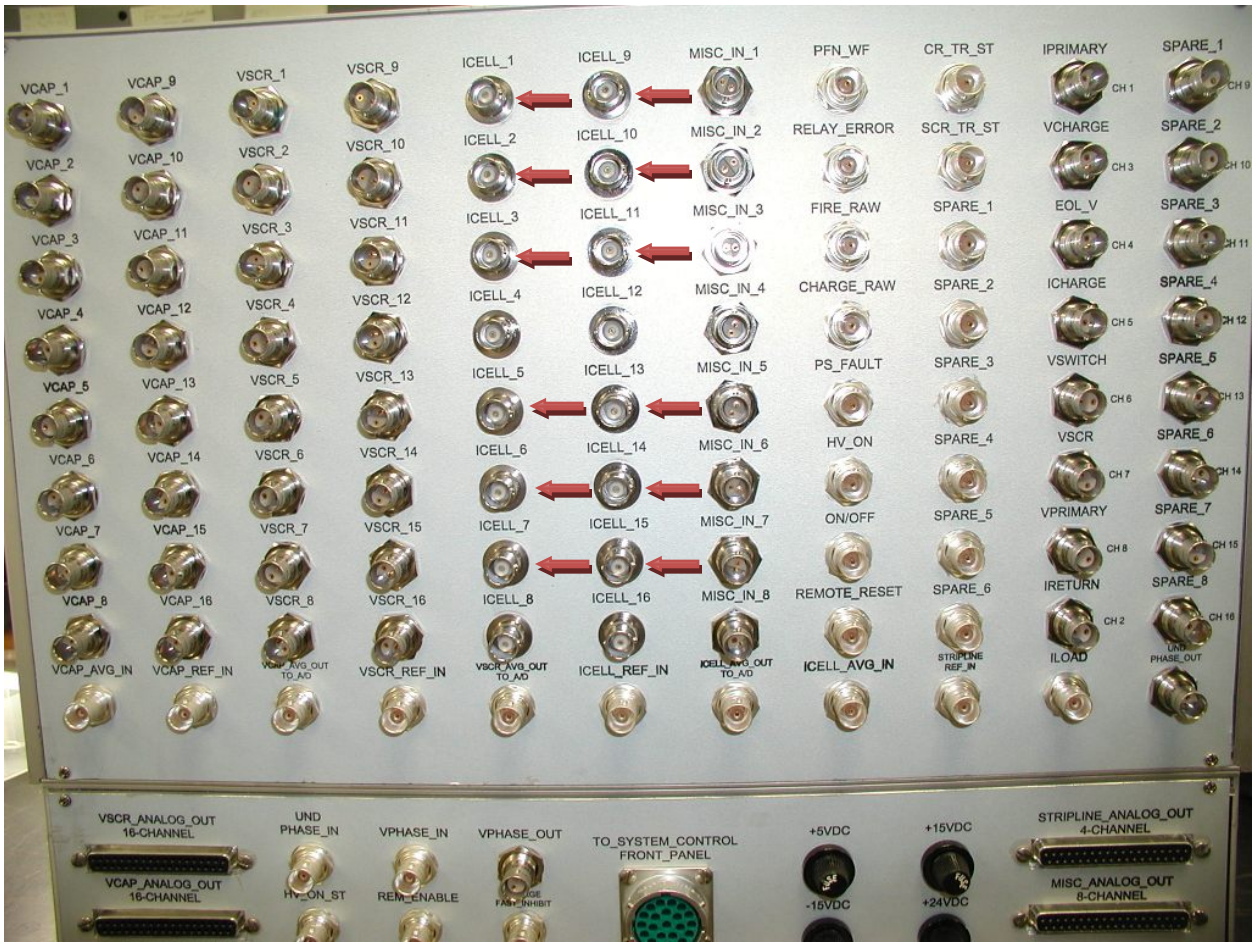


Figure 7.

Check-list

NuMI Horn Power Supply polarity change check-list.

[ ] Power down system.

[ ] LOTO

[ ] Water off/drained	4 locations
[ ] Controls Voltage switch	1 unit
[ ] Controls current signal adapters	12 units
[ ] Output SCRs	12 units
[ ] Isolation diodes	12 units
[ ] Anti-parallel diode	1 unit
[ ] Recovery diodes	12 units
[ ] Electronic crowbar	1 unit
[ ] PEI	1 unit
[ ] Hydrostatic test – leak check	
[ ] Enclosure secured, Key in panel	1 unit
[ ] SL Blower ON (Breaker #12)	1 unit
[ ] Locks. Caps grounded tag	As needed