

NuMI Horn Test Power Supply Safety Analysis Report

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Purpose: A power supply system has been built for the purpose of pulsing the prototype NuMI focusing horns. Various field, temperature, vibration, and life tests will be carried out on the horns using this equipment. When construction of the operational power supply is completed, it will replace this unit. The charging source and capacitor bank, working together, can produce the pulse train as shown in Figure 1. Continuous operation with a rep-rate of 1 Hz, or less, can be achieved.

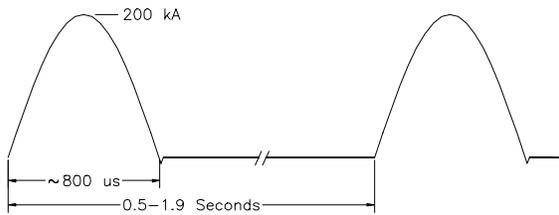


Figure 1. Output waveform from capacitor bank

The circuit contains a capacitor bank of 80 mF, total, that is charged by a 240kW PEI power supply configured to provide up to 800 volts. The capacitor bank is divided into four independent sections. Each section is isolated from the others and the charging source by diodes, and from each other and the load by SCRs. A schematic of the equipment is shown in Figure 2.

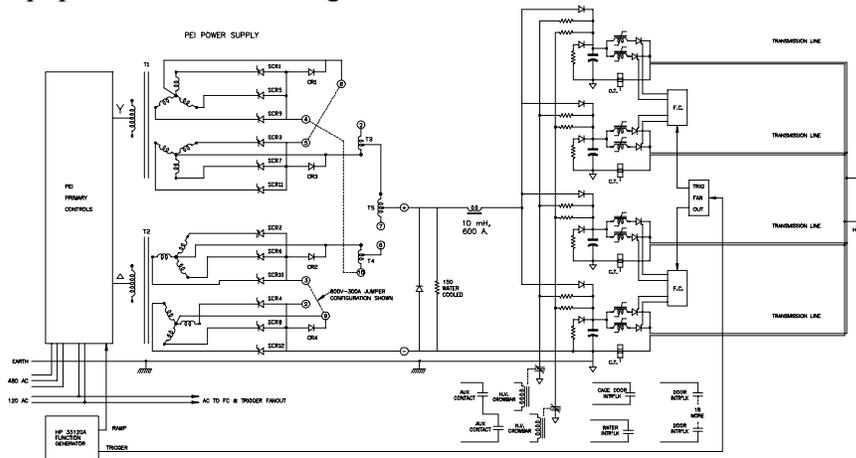


Figure 2. Schematic of PEI charging supply and capacitor bank

Equipment: The equipment is installed in the south end of the MI-8 service building. The capacitor bank is constructed within a heavy-duty enclosure equipped with multiple doors, each secured with latches and key locks. The PEI is a standard unit but modified to include later model regulation electronics and a lock on its rear doors. The capacitor bank is switched with eight parallel SCRs and will be connected to the horn load via an

switches are connected into the PEI interlock chain to turn off the charging supply upon entry.

Two high voltage, high current, shorting (Ross) relays with independent discharge resistors are series connected across each of the capacitor banks for discharging the capacitors upon turn-off of the charging supply. The relays close the resistors across the capacitor banks while in the de-energized state. The dual shorting scheme provides redundancy for additional electrical safety. The shorting relays are mounted such that gravity assist is accommodated for fail-safe operation, removing dependence upon springs for contact closure. Auxiliary contacts on the shorting relays are connected into the PEI interlock chain to maintain the charging source in by-pass mode unless both shorting relays are energized.

- Current: Each capacitor bank is designed to provide up to $50\text{kA}_{\text{Peak}}$ output into a common horn load via a parallel plate stripline, providing a total of up to $200\text{kA}_{\text{Peak}}$ output current. Each capacitor bank is configured with copper bus of $1/4" \times 4"$ dimension, equal to 1 in^2 in cross-section. During $1/2 \text{ Hz}$ operation, bus current will be $725 \text{ A}_{\text{RMS}}$. At 1 Hz operation, bus current will be $1000 \text{ A}_{\text{RMS}}$. 2Hz operation, $1414 \text{ A}_{\text{RMS}}$, may be possible with additional cooling.

The stripline external to the capacitor bank enclosure will be constructed with $3/8" \times 12"$ aluminum, 6101-T6, electrical bus material and can operate at $7250 \text{ A}_{\text{RMS}}$ continuously.

Any access to high current connections requires LOTO procedures to be followed so that no hazard exists.

- Stored energy: Each capacitor bank cell, 0.02 Farads , will store 6.4 kJ when operating at 800 volts . Each diode providing capacitor cell isolation from the PEI cell is rated for $2.4 \text{ kV}_{\text{PIV}}$ and $450 \text{ A}_{\text{IF(AV)}}$. The Eupec SCRs switching the output are rated for 2 kV VDRM and VRRM . Six different makes/values of capacitors are used in the circuit and are rated 1.35 kV , 1.5 kV , 2 kV , 2.5 , and 5 kV . Case construction is of a style nominally rated for 20 kJ containment. A resistive ground stick is provided to discharge the four capacitor groups. A hard ground stick is also provided for maintaining a ground while the permanently anchored grounding clip leads can be secured.

- Induced voltage on Equipment During Faults to Ground: The PEI enclosure, the capacitor bank enclosure, and the single point ground bus within the capacitor enclosure are all bonded to the MI-8 building ground system grid via 500 mcm bare copper conductor. All ground conductors are sized to handle any fault current that may occur.

- Acoustic: It is not anticipated that the sound levels will be high enough to be hazardous to building occupants but sound levels will be measured if so indicated.

- Hazardous Materials: The capacitors are of six different models by three different manufactures. They are:

General Electric;
900 μF - 1.35 kV_{DC}
Impregment - Castor Oil. Units labeled "No PCBs"

Maxwell Laboratories;
240 μF - 5 kV_{DC}
400 μF - 5 kV_{DC}
1200 μF - 2 kV_{DC}
Impregment - Castor Oil for all of the above

Westinghouse;
480 μF - 2.5 kV_{DC}
1600 μF - 1.5 kV_{DC}
Impregment - WEMCOL - the Westinghouse capacitors are labeled that they do not contain PCBs.

MSDSs are on hand for these materials.
No other known hazardous materials exist within the equipment.
The enclosure design is such that it will contain any oil spill or leakage.

LOTO: Due to there being two sources of energy for the PEI, and the potential for stored energy in the capacitors, a written LOTO procedure will be necessary. The LOTO procedure describes the steps to safely lock out energy sources and discharge stored energy.

480 V_{AC} power for the PEI is supplied via a dedicated circuit breaker in power panel DHP-MI8-1, breaker #17. It is located in the southeast corner of MI-8.

The circuit breaker for the 120 V_{AC} control power in the PEI is located in power panel PP-MI8-1A-5-A1, breaker #5.

The circuit breaker for the 120 V_{AC} power for the capacitor bank enclosure is located in power panel PP-MI8-1A-5-A1, Circuit Breaker #3. However, all 120 V power in the capacitor bank enclosure is guarded by utility boxes and guards over terminal strips.

All breakers are fitted with a locking device for LOTO locks.

Warning Device: A flashing red warning light is installed on the top of the capacitor bank enclosure, on the end nearest the horn load. It will operate at any and all times the PEI charging supply is in the "DC ON" mode.