BROOKHAVEN NATIONAL LABORATORY **Spec. No.: CSN 0256**

RELATIVISTIC HEAVY ION COLLIDER Issue Date: October 21, 1996

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Title: 225 KW Rectifier Module for the Star Pole Tip Trim Magnet Coil

QA Category: A2

• Cognizant Engineer: _____

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REVISION RECORD

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This specification consists of 27 pages and 2 Figures

1.0 Scope

1.1 This specification, in conjunction with other documents, defines the performance, design requirements, configuration, construction, materials, quality assurance, inspection, testing, workmanship, and packaging of SCR controlled rectifier modules. These rectifier modules shall be installed by Brookhaven National Laboratory (BNL) as part of a large magnet powering system and must operate continuously for long periods of time in an unmanned area. The rectifier module must exhibit a high level of reliability and shall be thoroughly interlocked.

1.2 The rectifier modules shall be SCR controlled, three phase, full wave, full control, twelve (12) pulse, continuous duty, AC to DC converters. Each module shall be comprised of two (2) each, 3-phase full wave SCR bridges with the bridge outputs connected in series. There shall be a free wheeling diode (FWD) placed across the rectifier modules output terminals. The rectifier module shall be used to convert BNL supplied, three phase, 60 hz power into 140 VDC (nominal operating), 1600 amp, 225 kW, highly regulated, fully controllable power for the STAR detector pole tip trim magnets. The STAR pole tip trim magnets are an inductive / resistive load. The module shall be enclosed in an all metal enclosure and shall be water cooled. **The main rectifier transformers will be external to the rectifier module and will be supplied by BNL. The transformers are not covered in this specification and reference shall be made to the transformer data for rectifier module design purposes only.**

1.3 The rectifier modules will be part of a complex group of power supplies, (see Fig. 2), which make up the power system for the STAR detector magnet. The rectifier modules shall be designed to meet specifications for interactions between these power supplies and itself by both direct electrical and by magnetic coupling.

1.4 BNL will supply all regulation circuitry except for the required current and voltage transducers. The output of BNL 's feedback amplifier will feed additional BNL circuitry that will produce the phase adjustable low level SCR gate triggering pulses. The Seller will supply the circuitry to accept these pulses and transmit them via fiberoptic cable to the Seller supplied high level triggering circuitry (see 4.4.1 & 4.4.2).

1.5 The Seller shall supply all labor, materials and equipment necessary to design, manufacture and test the rectifier module described in this specification. The seller shall also provide all labor and resources to produce detailed up to date documentation of the rectifier module as built. It shall be the responsibility of the seller to ensure that the rectifier module meets the requirements of this specification in a highly reliable and conservative fashion. The equipment shall be designed to have an expected service life of greater than twenty years.

1.6 The design of these rectifier modules must be conservative, using standard commercially available component parts and techniques that insure high reliability and minimum maintenance. The detailed parameters for these units are given in the Specification Data Sheets that are attached to the end of this specification. After award of contract, no deviation from this specification is permitted unless written approval is obtained from the BNL Division of Contracts and Procurement.

2.0 Applicable Documents

2.1 The following documents form a part of this specification and are to be used as standards in the design and manufacture of the power supplies. Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the Invitation to Quotation. Exceptions to these standards shall be approved in writing by Brookhaven.

Number	Title
BNL - QA -101	Supplier Quality Assurance Requirements
Code of Federal Regulations Title 29, Section 1910	OSHA General Industry Safety and Health Regulation and Standards
NEMA	SG-5, Indoor Power Switch Gear
NFPA 70	National Electric Code
IEEE 519	Harmonic Control and Reactive Compensation of Static Power Converters
IEEE 383	Vertical Flame Test
RHIC DS-1	RHIC Design Standard
CEI-IEC 146-1-1	International Standard-Semiconductor Converters

2.2 All rectifier modules supplied under this specification shall be in strict accordance with the latest standards, publications and definitions of the IEEE, ANSI, NEMA and NEC where applicable. The rectifier module shall be manufactured in accordance with the best of existing techniques and recognized engineering practices. In all cases reference shall be made to recommended procedures of standards of the above organizations. Where this specification differs from the above standards and procedures, this specification shall apply, (see 3.1.3).

3.0 Requirements

This section of the specification describes the performance and physical characteristics of the units required. Alternate products or schemes offered by the seller that may provide equal or better performance and reliability will be subject to approval by BNL.

3.1 Parts, Materials and Processes

3.1.1 Materials that may be defined as hazardous in accordance with Title 29, Code of Federal Regulations, Section 1910.1200 shall not be used. More specifically, asbestos or

asbestos-type insulation, insulating or dielectric fluids containing PCB's, etc., **shall not** be used. Where a choice of materials is available, eg. cables, support hardware, etc., preference shall be given to material or equipment exhibiting a higher level of fire retardancy, low oxygen content, etc.

3.1.2 The specifications for the various portions of the work describe certain special materials, processes and products of manufacture that will be required unless equal construction is specifically approved in writing by the BNL Division of Contracts and Procurement. Should the seller propose to furnish other "equal" materials, processes, or products either in substitution for, or as an alternate to the specifications, such substitution can be approved by Brookhaven only if described in full detail. The Cognizant Engineer's decision as to the equality of any materials, processes and products to those specified shall be final, but the approval of BNL shall not relieve the seller from his responsibility concerning such work or affect the guarantee covering all parts of the work.

3.1.3 The BNL Cognizant Engineer shall have final approval as to the determination of design parameters, operational margins, specification interpretation, control, protection and testing. Differences between the seller's proposal and the standards or Brookhaven's requirements shall be resolved by the Cognizant Engineer's determination. Sellers shall obtain written approval from BNL before proceeding with the final design and fabrication. No deviation from the specification will be allowed unless specifically authorized by BNL in writing.

3.1.4 The seller will be held responsible for the design, construction and testing of the rectifier module. However, the seller will not be held responsible for the installation and system testing at Brookhaven.

3.2 Submittals by Seller

3.2.1 The seller shall submit a proposal that gives a **PARAGRAPH by PARAGRAPH** response as to how he intends to comply with this specification. Any exceptions that the seller may take to the specification shall be clearly noted in the proposal. The seller shall state in the proposal that he is in full compliance with all aspects of these specifications that are not noted as exceptions.

3.2.2 The seller shall fill out the attached form entitled "Seller Data Sheet" and return it with his proposal. All exceptions to this specification shall also appear in the exceptions section as per section 3.2.1.

3.2.3 The proposal shall include a list of controlled rectifier modules with similar ratings and where the construction is identical to that which will be used for this proposal that the seller has produced and shipped. The list shall include the performance data for these modules, the purchaser's name and shipping date.

3.2.4 The seller shall describe in his proposal the testing capabilities of his facility and the electrical capacity of the test site.

3.2.5 Three sets of preliminary outline drawings showing the overall dimensions, all component placements, preliminary schematics and a preliminary manufacturing schedule shall accompany the proposal.

3.2.6 Three (3) weeks prior to first article testing, the seller shall submit for BNL's review and approval, a copy of the final test procedure.

3.2.7 The seller shall specify in detail the guarantee period and its provisions in his proposal.

3.2.8 Documentation

3.2.8.1 Upon delivery of the equipment five (5) sets of as built, signed, final prints shall be supplied by the Seller. One set of the final as built drawings, which are capable of high quality reproduction, shall be furnished. These prints shall be made to the highest professional drafting standards. Computer CAD system drawing plots shall be provided on 3 ½ inch floppy disk or CD-ROM in the format of "AutoCAD", or "View Logic" drawing plot files. Drawings shall conform to the guidlines set forth in RHIC Design Standard DS-1 revision 5.

3.2.8.2 Five (5) sets of bound design and operations manuals shall be shipped with the equipment. They shall include all test results, final parts lists, recommended spare parts lists, technical descriptions of the power supply operation and maintenance recommendations, description of critical adjustments and potentiometer settings, and data sheets on gauges, meters, fuses, semiconductors, relays, valves, and other pertinent components.

3.2.8.3 A log shall follow the module through production. This log shall contain critical settings for the module and shall serve as a history of its production. A copy of this log shall be supplied to Brookhaven. The log shall contain as a minimum potentiometer settings, torque settings, test results, and trip settings.

3.3 Design Reviews

3.3.1 Prior to awarding a contract under this specification a pre-award meeting shall be held at the seller's facility. At this time a preliminary review of the submitted design will be held and the capability of the seller to produce these rectifiers in a timely manner will be evaluated.

3.3.2 The final design review (FDR) shall be held ten (10) weeks after receipt of order and prior to the start of fabrication. Three (3) sets of all electrical schematic drawings, mechanical assembly drawings, a manufacturing schedule, a preliminary acceptance test procedure, and a complete parts list shall be submitted to BNL at least two (2) weeks prior to the FDR date. Agreement shall be reached during the FDR not only on the drawings and material submitted, but also on the seller's manufacturing plan, preliminary test procedure and schedule. Components and materials used in the cooling system shall also be reviewed at this time. The results of the FDR shall be documented by the seller and submitted to BNL for approval. After written approval of the FDR by BNL the seller shall promptly begin the assembly of the rectifier modules.

4.0 Performance and Design Characteristics

This section of the specification describes the performance and physical characteristics of the units required. Alternate products or schemes offered by the seller that may provide equal or better performance and reliability will be subject to approval by the BNL Cognizant Engineer.

4.1 Controlled Rectifier Modules

4.1.1 The thyristor modules shall be supplied completely assembled in an all metal enclosure together with the passive filter system, reversing switch, 480 volt vacuum contactor, AC current transformers, fuses, DC potential transformers, protection, control and monitoring circuitry. A simplified schematic diagram is shown in Fig. 1.

4.1.2 The rectifier modules to be supplied shall be dual series connected (SCR bridge A & B), three phase, full wave, full control, SCR bridges with two separate three (3) phase AC inputs. The two AC inputs, supplied by BNL, will be phase shifted 30 electrical degrees from each other. The DC output of the two bridges shall be connected in series to produce a 12-pulse output (see Fig.1). In all cases the construction of the rectifier module shall exemplify symmetrical, balanced construction so that stray inductances and stray capacitances (i.e. series and shunt reactances) are equal in the three phases with respect to each SCR as well as between bridges and ground.

4.1.3 One of the most exacting requirements of the rectifier modules is to provide balanced 12-pulse DC output voltage that is as close to the theoretical ideal as possible. Typically, the amounts of subharmonic output components of voltage ripple should be less than three percent (3 %) of the fundamental. This is measured as a ratio of each component peak to peak to the fundamental peak to peak value. Therefore, reactance unbalance and SCR timing errors and delays must be minimized. The timing errors refer to both trigger circuitry errors as well as inherent device errors (e.g., excessive SCR T-ON or T-OFF variations).

4.1.4 It is the intent of this specification that the surge ratings of the individual SCRs used and the (internal) construction of the module shall be such that a module can handle the full expected fault current of the system until the external protective devices can safely shut the system down. The fault current time period will be for ten (10) power line cycles at 60 Hz. or less.

4.1.5 The rectifier module will be controlled by the seller supplied vacuum contactor connected to the primary side of the rectifier transformers. This contactor and the seller supplied CT's monitoring the line currents shall be mounted in an AC input compartment of the rectifier module. The seller is required to supply those sensors needed to activate protection circuitry and support the application of externally generated signals needed for the protection of the module.

4.2 Transformer Data

The rectifier transformers will be purchased under a separate specification and order. All quotes in response to this specification shall not include these transformers. Reference made to the transformer data is for rectifier module design purposes only.

4.2.1 140 KVA Transformer.

4.2.1.1	Number of Units Required……..	4
4.2.1.2	Rating, KVA. (OA / FFA)……	140 / 170 KVA
4.2.1.3	Winding configuration with electrostatic shield……	Extended Delta-Wye
4.2.1.4	Relative Phase Shift, Transformer T1 a……	+15 Electrical Degrees
	Transformer T2 a ……	- 15 Electrical Degrees
	Transformer T1 b……	+15 Electrical Degrees
	Transformer T2 b……	- 15 Electrical Degrees
	T1 a and T2 a are in the same oil tank	
	T1 b and T2 b are in the same oil tank	
4.2.1.5	Primary voltage, Volts (+10%, -5%)……..	480 Vrms, 60HZ, 3 Phase
4.2.1.6	Secondary voltage, Volts	
	(Secondary tap voltages defined at 480 V primary.)	
	Secondary Tap 1 (100%), volts……	60 Vrms
	Secondary Tap 2 (90%), volts……..	54 Vrms
	Secondary Tap 3 (80%), volts……	48 Vrms
	Secondary Tap 4 (45%), volts……..	27 Vrms
4.2.1.7	Secondary current, max, line amperes……	1347 Amp
4.2.1.8	Transformer Impedance (max) 90% tap……..	5.0%.
	Max difference between matching transformers…..	mean +/- 5.0%
4.2.1.9	Voltage Balance, no load (phase to phase)…….	0.1%
	Max difference between matching transformers…	0.1%
4.2.1.10	Efficiency……	> 98%
4.2.1.11	Load Duty Factor……..	Continuous
4.2.1.12	Available short circuit current (to primary terminals)	60 kAmp
4.2.1.13	Material, windings, bus bar, leads…….	copper
4.2.1.14	Cooling ……	OA/FFA
4.2.1.15	Ambient Air Temperature……	-30 to +45 Degrees C.
4.2.1.16	Temperature Rise, Deg. C (max)…….	55 Degrees C
4.2.1.17	Humidity……..	100%
4.2.1.18	Altitude……	< 100 meters
4.2.1.19	High potential test voltage (hv terminals)……	2.5 kV rms
	(lv terminals)……	2.5 kV rms

4.3 Power Semiconductor Ratings

4.3.1 The peak inverse voltage (PIV) and peak forward voltage (PFV) rating of all power semiconductors shall be rated for three (3) times their peak circuit operating voltage or greater. The minimum PIV and PFV for the main bridge SCRs shall be 1000 V or greater and for the FWD assembly shall be 1500 V or greater.

4.3.2 The seller shall limit **ON** and **Off** or other induced switching transients to 50 percent of the published inverse and forward voltage ratings of all power semi-conducting devices.

4.3.3 The SCRs shall be protected against high di/dt stress and dv/dt breakover. The protection may include, but not be limited to, RC snubber networks, series inductors, symmetrical avalanche suppression devices, metal oxide varistors, or selenium surge suppressors. Appropriate overvoltage limiting devices shall be placed at the three AC input lines of each bridge. In RC snubber network designs, the resistors shall be non-inductive and the capacitors shall be of extended foil construction and made for commutation service. Fuses shall be required to isolate failed protection devices such as MOV's and selenium surge suppressors on the high power circuits. In these cases, fuse status monitoring shall be provided to the PLC (see 4.6.6) for interlock control and status.

4.3.4 The continuous current rating of all silicon rectifiers and SCRs shall be at least two (2) times greater than the maximum RMS current the device will conduct during operation of the rectifier module.

4.3.5 The number of SCRs used in the bridges shall be limited to one (1) SCR per leg; series or parallel SCRs will not be permitted. The seller shall provide in his proposal data sheets that indicate the type of SCR chosen and its ratings.

4.3.6 The SCRs and FWDs shall be water cooled. The units shall be mounted and clamped on water cooled heatsinks according to the recommendations of the semiconductor manufacturer. The maximum junction temperature shall not exceed 100° C under worst case load conditions with a maximum inlet water temperature of 40° C. Individual cooled SCR heat sinks shall have an over temperature protection scheme, such as thermostat type switch, mounted close to the SCR which shall be set to trip before the SCR junction temperature reaches 100° C. The output of these switches shall be connected to the PLC (see 4.6.6). The seller may elect to support over temperature protection using an alternate procedure. The seller shall provide calculations showing the expected temperature rise with his proposed cooling and protection scheme. The over temperature monitoring circuitry must meet the high potential test in section 6.6.

4.3.7 FWDs shall be installed across the output of the rectifier module before the output DCCT. They shall be rated to handle the full rated DC current of the system on a continuous basis. If it is required to use paralleled units, current equalization or balance circuitry must be provided.

4.3.8 The SCRs and FWDs shall be mounted with consideration for replacement and maintenance accessibility, the sellers preliminary drawings shall show their position in the rectifier modules.

4.4 SCR Bridge Triggering

4.4.1 The seller shall supply the high level, hard-fired gate triggering circuitry for all SCR triggering. The high level triggering must be capable of turning on all the SCRs within the recommended manufacturer device ratings and also meet the balancing specifications of section 8.0.

4.4.2 Brookhaven will supply the low level input pulse to the sellers low level gate triggering circuitry. Optical isolation will be required between the sellers low level gate trigger circuit and high level trigger pulse circuitry. The use of fiber optic links between the seller's high and low level circuitry is the preferred method to achieve this isolation. The seller shall provide the fiber optic receivers, transmitters and fiber optic cables. The Brookhaven input to the seller's low level triggering circuitry shall be located in the customer control compartment.

4.4.3 The Brookhaven low level trigger pulse capability is 5 volts and 40 milliamperes. The rise time (10 to 90 percent) is less than 0.5 microseconds. The range of the SCR triggering will be greater than 160 electrical degrees to reliably trigger the SCRs from full rectify to full invert. The length of the signal is 120 degrees.

4.4.4 The sellers SCR drive circuits shall have high drive power capability (i.e. hard drive) to reduce jitter variations and total turn on time. Reverse gate bias circuitry is desirable for reliable operation while forward bias or stray positive gate bias should be avoided to prevent a reduction of blocking capability. The Brookhaven supplied low level input pulse shall be amplified to hard fire each SCR device. The sellers provided high level trigger system shall be capable of supporting the above parameters on each SCR. The power source for the gate drive circuits may be derived from the SCR anode power or supplied from an external control power source via properly rated isolation transformers.

4.4.5 The seller supplied high level gate trigger circuitry shall exhibit minimum delay from the Brookhaven input low level pulse to the final output gate pulse(s). The total delay (including dead time and rise time) shall be less than **1.0 microsecond**. The time jitter of the high level gate pulses shall be less than **+/-0.5 microseconds**. The gate trigger hard drive circuitry shall be mounted close to the individual SCRs to prevent delays and to reduce the possibility of false triggering due to noise pickup in long cable runs.

4.4.6 The seller shall use construction and wiring techniques designed to minimize noise pickup in the triggering circuitry. This shall include the use of twisted shielded cable, proper grounding techniques, and electrostatic / electromagnetic shielding of sensitive components. All printed circuit board designs shall have large traces, ground planes, and large area pads to accommodate the high gate / cathode currents. The design shall include an adequate number of test points to facilitate troubleshooting and set up.

4.4.7 The low level triggering system will be supplied by Brookhaven for testing of the module, the design data for the firing system will be finalized after the award of the rectifier module contract.

4.4.8 The sellers trigger circuitry will be reviewed and approved at the time of the FDR meeting. Details of the circuit design will be required two (2) weeks prior to the FDR, see section 3.3.

4.5 LRC Output Filter

4.5.1 The rectifier module shall contain a high current low pass filter to attenuate the output voltage ripple. This shall be a passive, damped, filter composed of a four terminal , coupled, series choke, a shunt capacitance, and a shunt resistive / capacitive (RC) damping section. The resistor shall be chosen to approximately damp the LC filter close to critical damping. The DC blocking capacitor shall have at least 5 times the basic filter capacitance value. One leg of the choke shall be installed in each of the output DC buses (see figure 1.).

4.5.2 The peak to peak output voltage ripple shall not exceed 0.66% of the rated DC output voltage for all voltage tap settings (at the worst point between 10% and 100% of output voltage) when fed from the transformer described in section 4.2. See the specification Data Sheet (section 8.0) for complete details.

4.5.3 The passive LC RC damped filter shall attenuate all the frequency components of the rectifier power supply output voltage above the specified cutoff frequency at the specified rate.

4.5.4 The transient response of the filter's output voltage to a step change in input voltage or a step change in load shall have an overshoot which shall not exceed 30% peak above the final output voltage and shall not be oscillatory beyond the first oscillation period.

4.5.5 The filter inductor (coupled, two legs) shall be braced for short circuit fault current. The windings and bus terminals shall be copper with class H insulation. The inductor shall be water cooled with a temperture rise of 30 degrees C max. Over temperature interlock protection shall be provided and shall be wired to the rectifier module's PLC (see 4.6.6) control system for interlock control and alarm indication. The over temperature contacts shall be normally closed and shall open for over temperature state, the contacts shall be suitable for 24 volt DC operation. The filter inductor system shall be capable of meeting the high potential test defined in section 6.6. The final inductance shall be constant to within +/- 10 % of the nominal value over a frequency range of from 0 to 10 kHz and over the full output current range.

4.5.6 All capacitors used in the filter circuit shall be fused, either individually or in groups, so that their rms current is not exceeded. Fuse failure interlock protection shall be provided and shall be wired to the rectifier module's PLC control system for interlock control and alarm indication. The fuse failure contacts shall be normally closed and shall open for fuse failure. The contacts shall be suitable for 24 volt DC operation. Fuse ratings shall take into account capacitor charging and discharging currents in addition to currents caused by voltage ripple.

4.5.7 The filter capacitors shall be rated to handle all applied voltages and shall be protected from the application of reverse voltage. Bleeder resistors shall be installed across each capacitor to ensure proper discharge of the capacitors when the rectifier module is turned off. The discharge time constant is listed in the specification data sheet. The capacitors shall be capable of meeting the high potential test defined in section 6.6.

4.6 Protection Devices and Control Circuits

4.6.1 The following devices or systems, (sections 4.6.2 through 4.6.15), shall be incorporated in the rectifier module and shall be used to interlock the module to internal and external control devices. All of the interlocks and controls of each module shall be connected to a programmable logic controller in the module control compartment. Some interlock and control devices shall be wired directly to terminal strips and to external protection circuits as well as to the programmable logic controller. These interlock circuits are defined under each device section. All control, interlock devices and circuits must meet the high potential tests of section 6.6.

4.6.2 The control voltage for the rectifier module shall be 24 volts DC. The input voltage for the 24 volt DC power supply shall be 120 volts AC externally supplied. The 24 volt power supply shall be provided by the Seller. The 120 volt AC power shall be housed in the module control compartment and shall be grouped together in one location and covered with a safety barrier and warning signs. A two pole, 120 volt, circuit breaker shall be provided by the Seller. Its operating handle shall be accessible without removing the 120 volt AC safety barrier.

4.6.3 A suitable EMI/RFI line filter shall be provided for 120 volt AC line control power. The filter shall be properly sized to exceed the maximum voltage and current rating of the control circuit.

4.6.4 A high current relay or contactor shall be provided which will be used to turn the 120 VAC power to all the rectifier module control functions on and off, (**Standby relay**). The relay shall also turn on all regulator and SCR triggering circuitry. Extra terminals shall be provided for connection of BNL control circuitry. The relay shall be an Allen-Bradley type 700DC-P400Z24 or approved equal with a coil voltage of 24 VDC and 4 poles. The coil shall be controlled by the output module of the PLC and shall have a diode and an MOV connected across the coil to limit the back EMF to the PLC module. When the relay is de-energized (Auxiliary OFF command) all 120 VAC power shall be off except to the PLC and the PLC 24 VDC control power supply. An auxiliary contact from the standby relay shall be wired to an input module of the PLC for standby status verification.

4.6.5 The Seller shall provide a **master interlock relay** and it shall be connected to the PLC output module. The relay shall be an Allen-Bradley type 700DC-P400Z24 or approved equal with a coil voltage of 24 VDC and 4 poles. The coil shall have a diode and MOV connected across it to limit the reverse EMF the PLC output module will receive. The relay shall be located in the module control compartment. This relay will be used to trip the incoming 480 volt contactor which feeds the rectifier transformers. An auxiliary contact from the master interlock relay shall be wired to an input of the PLC for ready status verification.

4.6.6 The Seller shall provide the following programmable logic controller devices in the rectifier module as a minimum. Additional input / output modules may be needed based on the requirements of the sellers design. These additional modules shall be provided by the seller. The Allen-Bradley SLC500 devices specified are part of a standard product line used at BNL for all power supplies. The logic programming of the PLC will be provided by BNL and will be based on the final wiring schematic approval at the design review. The program will be supplied eight (8) weeks after the final design review approval. The PLC Ladder Logic control program for the control and protection of the rectifier module will be provided by BNL on a EEPROM module.

4.6.6.1 One each, 10 Slot Rack, No. 1746-A10.

4.6.6.2 One each, power supply module, No. 1746-P2.

4.6.6.3 One each, SLC-5/02 processor module, No. 1747-L524.

4.6.6.4 One each, EEPROM memory module, No. 1747-M2.

4.6.6.5 One each, Remote I/O module, No. 1747-DCM.

4.6.6.6 Three each, 24 Vdc, 16pt Input module, No. 1746-IB16.

4.6.6.7 Two each, 24 Vdc, 16 pt module, No. 1746-OB16

4.6.7 Over temperature protection of rectifier cells will be required (see 4.3.6). The over temperature detection devices shall be thermostat type switches (or equal) with contacts that are electrically isolated from the heatsink, and must be capable of meeting the high potential test in section 6.6. The thermostats shall be automatic reset type with normally closed contacts suitable for operation on a 24 volt DC system. The trip point of the thermostat is to be set to protect the rectifier cells from exceeding the manufacturer's recommended maximum safe operating case temperature for the maximum junction temperature given in section 4.3.6. All the over temperature devices shall be wired individually to the PLC input module for interlock control and alarm monitoring.

4.6.8 Each phase of the AC input lines to each SCR bridge shall be fused. Current limiting fuses shall be selected to limit the peak let-through current to less than sixty percent (**60%**) of the SCR manufacturer's maximum specified peak one cycle surge rating (Itsm). Fuses shall not be placed in line with each individual SCR. Fuses shall be located in each AC input line of each SCR bridge. Parallel fuses may be used for proper coordination. A fuse monitoring system shall be provided. The fuse monitoring system shall provide fuse status information to the PLC for interlock control and alarm indication. The fuse monitoring system contacts shall be normally closed and shall open when a main fuse fails. The contacts shall be suitable for 24 volt DC operation. The fuse monitoring system must meet the high potential test in section 6.6.

4.6.9 The Seller shall provide a DC ripple detection circuit to monitor the output of the rectifier module for phase loss, system unbalance and misfiring SCRs. This interlock shall operate within five cycles of the 60 Hz line. The ripple detection circuit status shall provide status information to the PLC for interlock control and alarm indication. The ripple detection circuit contacts shall be normally closed and shall open when a fault condition is detected. The contacts shall be suitable for 24 volt DC operation. The ripple detection circuitry must meet the high potential test in section 6.6.

4.6.10 Three phase AC over current relays shall be provided by the Seller to sense AC over current in both sets of the primary inputs to the outdoor main rectifier transformers. The seller supplied current transformers shall be mounted in the rectifier enclosure near the seller supplied contactor. The over current devices shall provide interlock contacts **wired directly** in series with the master interlock relay contacts. The AC over current relays shall also provide status information to the PLC for other interlock control and alarm indication. The overcurrent relays shall be a CO2 type and have adjustable instantaneous and timed trip settings. The status and alarm contacts shall be suitable for 24 volt DC operation.

4.6.11 The rectifier module shall have a DC over current sensing device that has an adjustable trip setting from 10 percent to 110 percent of rated DC output current. The over current device shall use the modules internal DC transductor, DCCT, see section 4.7.6. The DC over current device shall be mounted in the module control compartment of the rectifier module. The DC over current device shall be **wired directly** in series with the master interlock relay coil so that , an over current condition shall open the master interlock relay contacts. The DC over current device shall also provide status information to the PLC for other interlock control and alarm indication. The status and alarm contacts shall be suitable for 24 volt DC operation.

4.6.12 Water flow switches shall be installed on the return leg of every parallel water path for loss of cooling water protection. A pressure differential switch shall be installed in each module to protect against loss of pressure. Shut-off valves shall be placed on every parallel water path to aid in back flushing the water paths. The water flow switches and the differential pressure switch shall be wired to the PLC for interlock control and alarm indication.

4.6.13 Door interlock microswitches shall be mounted on all hinged doors of the thyristor module that lead to high power AC and DC circuitry. The switches used shall be similar to the Micro-Switch type V-3. The door switches shall be wired directly in series with the master interlock relay contacts. The door interlock microswitches shall provide status information to the (PLC) for other interlock control and alarm indication.

4.6.14 The Seller shall provide DC overvoltage protection and interlocking circuitry which shall be capable of protecting the thyristor module from overvoltage conditions, at the DC terminals. This protection shall be so designed that it can be activated by internal sensing within the module. The overvoltage protection equipment shall also provide a detection circuit that will be wired directly to the master interlock relay contacts. Status information shall also be provided to the PLC.

4.6.15 The Seller shall provide a FWD assembly across the output terminals of the module to protect the module from transients caused by an interruption of the inductive load current. The FWD's must be able to continuously carry the full load current. The FWD's shall not be fused.

4.6.16 A DC current monitoring device similar to a Liaisons Electroniques Module LT series shall be used to monitor the current through the FWDs. When the current through the FWDs exceeds an adjustable limit a contact shall close issuing a warning to the PLC. The limit shall be adjustable from 10% to 100% of the DC output current rating.

4.6.17 A cubicle over temperature interlock shall be provided by the Seller. The device shall be adjustable, between 100° F and 200° F, and shall provide contacts for the PLC.

4.6.18 All doors shall have provisions for applying a captive Kirk key interlock (which will be provided by BNL) or other suitable protection devices.

4.6.19 Control circuits shall be designed in a fail-safe manner so that loss of power does not result in a hazardous operating condition. Protective interlock circuits and power supply controls shall be designed so that reactivation of the interlock circuit (i.e., completing the circuit) will not result in an automatic restoration of power to the equipment.

4.6.20 All faults and statuses shall be isolated and buffered and brought out to the programmable logic controller (PLC). Electrical isolation shall be accomplished by opto-couplers or relay contacts. All controls shall operate remotely via the PLC. For local operation, a "Local / Remote" toggle switch and, "Off", "Standby", and "On", push buttons shall be provided on the units front panel. These controls shall be wired to the PLC.

4.6.21 All protection and monitoring devices and circuits shall be properly isolated from the main power circuitry up to the high potential voltages of 6.6.

4.6.22 There shall be local "Off," "Standby," "On," "Fault", and "Polarity" indicating LED's on the power supply front panel. These shall be wired to the PLC.

4.6.23 The status of all interlocks shall be brought to the PLC. The following is a list of some of the interlocks which shall be required in the base proposal. The exact number of status readbacks and alarms required to adequately protect the module cannot be finalized until the Sellers design is complete. This list will be finalized at the FDR.

4.6.23.1 Incoming line AC Overvoltage (T1 & T2)
4.6.23.2 Incoming line AC Overcurrent (T1 & T2)
4.6.23.3 Incoming Phase Imbalance, loss of phase, phase rotation, DC ripple
4.6.23.4 DC Over current
4.6.23.5 SCR Over temperature including location
4.6.23.6 SCR Failure
4.6.23.7 FWD Over temperature
4.6.23.8 Filter Choke Overtemperature

4.6.23.9 Filter Capacitor Failure - Capacitor Fuse Monitoring System
4.6.23.10 Cubicle over temperature
4.6.23.11 Water flow
4.6.23.12 Water differential pressure
4.6.23.13 Blown fuses-indication and location
4.6.23.14 Door interlocks
4.6.23.15 Ground Fault
4.6.23.16 FWD current

4.6.24 The interlock circuitry as well as the buffering/isolating scheme supplied by the Seller shall be approved by BNL prior to commencement of fabrication.

4.6.25 All interlocks and alarm circuits must be capable of meeting the high potential tests outlined in Section 6.6.

4.6.26 The module control functions will be determined by the PLC program and the hardware configuration of the module. The control functions will be as follows:

4.6.26.1 Auxiliary OFF - all power off except power to the 24 volt power supply and power to the PLC.

4.6.26.2 STANDBY- energizes all low level control (see 4.6.4) , interlock and regulating circuits (toward a ready state). Whenever a STANDBY command is given a reset command is also given. This RESET signal shall clear any fault condition that has previously occurred and no longer exists. The seller shall install a multi-contact "Reset" relay and wire it to the PLC.

4.6.26.3 FAULT-there is a fault condition. If the module is ON it will trip to STANDBY and if it is in STANDBY it will remain in STANDBY until a RESET clears the fault.

4.6.26.4 READY-the module is in standby and all faults are clear (see 4.6.5).

4.6.26.5 ON - the ON command energizes the system's main contactor and output current is available upon receipt of gate drive signals. The seller shall install a multi-contact "On" relay and wire it to the PLC and to the contactor terminals.

4.6.26.6 The rectifier module shall contain a ground detection system to monitor the DC output of the module and the load. The detection scheme shall be based on a current sensing relay in series with one of the power supply output terminals and ground (see figure #1). Since in normal operation either terminal may be at ground potential depending on the hookup of the power supply, provisions shall be made in the design of the module to easily change the connection of the ground detection circuit from one output lead to the other. The current detection relay shall have two set points which shall be adjustable (from 0 to 5 amps) and shall have auxiliary contacts interfacing to the PLC. One set point will be used as a warning alarm level and the second set point will be used as a trip level.

4.6.27 Provisions shall be made for two external BNL interlocks. One interlock shall be wired to the PLC input and the other shall be wired directly in series with the master interlock relay through an appropriate terminal board. Status of either of the remote interlocks shall be monitored and annunciated via the PLC.

4.7 Instrumentation

4.7.1 The following switchboard instruments and their appropriate selector switches shall be mounted on the front door of the thyristor module. The instruments shall be standard 4 ½ inch flush mounted and shall have an accuracy of +/- 3%. They shall be of the same manufacturer and shall be of the same series. The instruments shall be properly isolated for personnel safety, adequately protected against over voltage, and shielded individually against stray magnetic fields so that they remain within their design accuracy under all operating conditions.

4.7.2 The line to line AC input voltage of all three phases of bridge A and all three phases of bridge B. There shall be two meters and two selector switches to allow metering all six voltages. The seller shall supply the necessary potential transformers.

4.7.3 The line to line AC input voltage to the transformer after the contactor. There shall be one meter and one selector switch. The seller shall supply the necessary potential transformers.

4.7.4 The input current of all six input lines to main rectifier transformer shall be measured using the seller supplied CT's. There shall be one meter and one selector switch for the +15 degree transformer input (A) and one meter and one selector switch for the -15 degree transformer input (B). The input currents to bridge A and bridge B shall be measured using seller supplied CT's. There shall be one meter and a selector switch for bridge A and one meter and a selector switch for bridge B.

4.7.5 There shall be a DC voltmeter operated from an isolated DC potential transformer (DCPT) connected across the rectifier output terminals. The DCPT shall have a tolerance of +/- 1 %. The DCPT shall have a bandwidth greater than 10 kHz and be similar to the Liaisons Electroniques Module LV series. Two isolated and buffered front and rear panel outputs shall be provided for voltage monitoring. In addition an isolated buffered output shall be supplied to the BNL regulation circuitry. The bandwidth of the monitoring and regulation voltage signals provided to BNL shall be at least 10 KHz. A second DCPT shall monitor the output voltage of the filter. Isolated buffered outputs shall be provided by the seller for this DCPT identical to those described above.

4.7.6 There shall be a DC ammeter that shall operate from an isolated current transductor (DCCT). The output current measurement shall have an accuracy and stability of better than ±0.001%. A Hazemeyer type D.C.C.T. manufactured by Holec, a Danfysik Ultrastab series, or an approved equal, is to be used. Two isolated and buffered front and rear panel outputs shall be provided for local load current monitoring. In addition an isolated buffered output shall be supplied to the BNL regulation circuitry. The bandwidth of the monitoring and regulation

current signals provided to BNL shall be at least 10 KHz. The DCCT shall be installed after the passive filter so that it measures the load current only.

4.8 General Requirements

The detailed electrical requirements and parameters are listed in the Specification Data Sheets (section 8). The Module shall also meet the general electrical specifications that are given in the following sections.

4.8.1 The rectifier module shall be constructed with a view towards safety. All high voltages (greater than 125 Vac) shall be barriered or compartmentalized. All high voltages shall be labeled with BNL approved labels. Controls shall be physically separated from the high power circuits.

4.8.2 The frame of the module shall be grounded, but both output terminals must be able to float up to test potentials of 2500 volts rms with respect to ground.

4.8.3 The frame of the module shall have a ground pad which shall be welded to the main frame and equipped with a 3/8 inch tapped hole for an external ground connection.

4.8.4 The output voltage ripple of the module shall be less than the value given in the Specification Data Sheets. This value shall apply over the full range of output voltages.

4.8.5 The modules final DC output settling time to a positive or negative step change shall exhibit close to a critically damped response and shall not exceed the value specified in 4.5.

4.8.6 Any electrical cable and buswork used as a power feeder or jumper shall be of copper and of sufficient ratings and cross-section that the cables shall not experience a temperature rise of greater than 50 degree C at maximum load.

4.8.7 All low level control wiring shall be a type AWM appliance wire, 600 volt, 105 degree C, stranded copper conductor or approved equal. All wires shall be labeled for circuit identification at all termination points. Proper insulators and supports shall be used.

4.8.8 All cable insulation used in this system shall be of a self extinguishing, low flame propagation, low smoke type and meet IEEE 383 vertical flame tests. The Seller shall include in his proposal a list of the insulating material that will be used.

4.8.9 Each phase of the AC input terminals shall be sized for 1,500 amperes or greater. The AC terminals shall be phased A-B-C for each input set (A & B) , from left to right facing the AC compartment door and shall be clearly labeled.

4.8.10 The AC input shall be through the upper center or rear of the module. Access doors shall be provided for both transformer input hookups and for servicing. The doors shall be electrically interlocked with micro switches and be capable of being mechanically locked with Kirk type locks.

4.8.11 The DC output bus compartment shall be located in the upper rear of the module. This area shall be isolated from all other compartments. Access doors shall be capable of being mechanically locked with Kirk type locks and shall be electrically interlocked. Doors or easily removable panels shall be provided to facilitate the operation of the dc reversing section (4.9).

4.9 DC Reversal

4.9.1 The DC output buswork shall include provisions for mechanically reversing the output polarity. The reversing section shall consist of DC bus and jumpers or links. The design of this section shall be done with ease of reversal as a major objective. The links shall be rated for full continuous current and when opened shall be capable of holding off 2500 volts DC.

4.9.2 Microswitches shall be installed which monitor the reversing sections bus configuration. The two polarities will be labeled "A" and "B". The microswitches shall be electrically isolated from the output bus so that they can be grounded when the output bus undergoes the high-potential tests described in section 6.6.

4.9.3 The position of the microswitches shall be monitored by the PLC and front panel lights shall indicate either "A" or "B" polarity. "A" polarity is defined as normal and "B" polarity as reversed.

5.0 Mechanical Considerations

5.1 The equipment shall be constructed in an all-metal cabinet which shall be in accordance with NEMA standards for Indoor Power Switchgear as per publication SG5, latest edition.

5.2 The equipment shall be partitioned into compartments. The purpose of these compartments is to insure that access to electrically dangerous potentials can be isolated and through a key coordinated locking arrangement exposure to electrical hazards can be prevented. This unit will be operated in conjunction with other power sources which will be galvanically connected to its output.

5.3 The module shall have a control compartment which shall be used to enclose all of the module controls, the programmable logic controller, over current devices, relays, protection, interlocks, system monitoring and status indications. This compartment shall be physically isolated from the high power compartments and shall be behind an unlocked door. The door shall not be interlocked. This compartment shall not have any exposed voltage greater than 125 volts AC or DC. Voltages greater than 10 volts ac or 50 volts dc shall be barriered.

5.4 The cabinet shall have a customer control compartment suitable for mounting standard 19 inch rack mounted equipment. The compartment shall be a minimum of 29 inches deep and shall be the full height of the rectifier cabinet. The compartment shall have a lockable front door.

5.5 Provisions shall be made for lifting the equipment by either overhead crane (e.g. lifting eyes) or fork lift (e.g. channels or I-beams). Such requirement will be finalized at the Design Review. The frame shall be made sufficiently rigid so that lifting and relocation shall not cause deformation or door misalignment.

5.6 The Seller shall provide an estimated module size, weight, and preliminary layout drawing in his proposal. The maximum dimensions of the units shall be within the values given in the Specification Data Sheets.

5.7 All bolted busbar, fuse, and rectifier joints shall use Belleville washers, flat steel washers, lock nuts and a joint compound approved by Brookhaven. All bolts, washers and nuts shall be stainless steel.

5.8 All bolts in blind locations shall have captive hardware.

5.9 All air filters shall be mounted on the outside of the unit and be of a size and type acceptable to BNL.

5.10 The accessories, materials and supplies used on these modules shall be of the highest quality or specification grade wherever possible. The Seller shall list in his proposal the manufacture of fuses, relays, receptacles, terminal strips, wire, hardware, etc. Auxiliary relays shall be enclosed in dust proof cases and mounted in the module control compartment.

5.11 The finish of the cabinets shall consist of degreasing of the unit followed by a coat of rustproofing paint and two coats of synthetic resin enamel, color "light blue" as per Federal Standard No 595A, Color No 35240.

5.12 The noise level three feet away from the power supply from all sources within the cubicle including cooling fans, shall be less than 70 dB when the unit is on and operating.

5.13 The Seller shall provide and affix a stainless steel or aluminum name plate on each unit that shall include the following information:

5.13.1 Manufacturer's Name and Address
5.13.2 Manufacturer's Type and Serial Number
5.13.3 BNL's Part Number
5.13.4 Complete Input Ratings
5.13.5 Complete Output Ratings
5.13.6 Cooling Requirements
5.13.7 Gross Weight of the Unit
5.13.8 Date of Manufacture
5.13.9 Specification Number

6.0 Testing

The module shall be fully tested at the Seller's plant to insure complete compliance with this specification. All facilities shall be provided by the Seller at his plant for a partial load test of the module. Three (3) weeks before these tests the Seller shall provide the final test procedure to BNL for approval. Included in this procedure shall be test data sheets and interlock check out lists. Final tests at the Sellers plant must be witnessed by Brookhaven prior to shipment, but final acceptance of the units shall be at Brookhaven.

6.1 The BNL Cognizant Engineer and /or his represent shall have access to the Seller's facility during fabrication and testing. The Seller shall provide the facilities and instrumentation at his plant to perform all necessary tests to ensure compliance with all parts of the specification. The Seller shall provide ten (10) working days notice in advance of the test date so that BNL can make the necessary travel arrangements.

6.2 The testing shall include but not be limited to the specific tests outlined below. The Seller shall supply a detailed test procedure for individual components, sub-assemblies, and the completed thyristor module to BNL at the final design review for approval (see section 6.0 for final procedure requirements).

6.3 SCR Testing

6.3.1 All individual SCRs and other power semiconductor devices shall be tested to rated PFV and PIV and the forward and reverse leakage currents shall be recorded.

6.3.2 All individual SCRs shall be tested near their actual operating current values to determine whether triggering characteristics are within specified values. T-on, I-holding, anode voltage, anode current, gate voltage and gate current shall be recorded.

6.3.3 The thermal ratings shall be checked on each SCR based on the maximum operating current, when mounted in its final heatsink and with specified water flow and temperature. The case temperature, current, forward drop and water flow shall be recorded, under stabilized conditions.

6.3.4 Units not within manufacturing ratings shall not be used in the final assembly. The Seller shall provide copies of the manufacturers specification data sheets for each type of device used.

6.3.5 Records of all tests shall be kept by the Seller for each item by device serial number in the form of traveler sheets. Copies of all traveler sheets shall be supplied to BNL.

6.4 Assembled Modules

6.4.1 A Heat run, as well as other performance tests shall be conducted on the completed assembled module at rated output current. The Seller shall install thermocouples on the SCRs and other points designated by the BNL Cognizant Engineer. The power circuits shall be operated continuously under a load acceptable to Brookhaven for a period of 24 hours. Short periods of downtime to make measurements or adjustments will be accepted but the total of all such downtime shall not exceed one (1) hour.

6.4.2 A hydrostatic pressure test shall be performed on the module at a pressure of 250 psi for one half hour.

6.4.3 The water flow in each parallel path and the total flow of water at a known differential pressure shall be measured. The temperature differential of the water paths shall also be recorded.

6.4.4 All interlock protection and status indication circuits of the full system shall be checked for proper operation. Actual fault conditions shall be induced where possible and control and annunciation shall be checked up to the PLC, I/O connections.

6.4.5 The fully assembled thyristor module shall be run lightly loaded (500 amps or greater) to full rated voltage.

6.4.6 ON, OFF, and Emergency OFF switching transients across the output of the high power semiconductor components shall be measured and recorded.

6.4.7 The voltage balance between the positive output terminal and ground, and the negative output terminal and ground shall be measured over a wide frequency range (0 to 100 KHz). The balance shall remain within specified values over this frequency range.

6.4.8 The time delay and jitter of the Seller high level SCR triggering circuitry shall be measured.

6.5 LCRC Filter

6.5.1 There shall be a factory heat run on the inductor before installation in a power supply. The inductor shall be run at the rated module dc current and the temperature monitored and recorded. The test shall be ended when the temperature rise is less than 1° C in two hours. The minimum length of time for this test is four hours.

6.5.2 A turn-to-turn insulation test shall be performed at 400Hz or higher. This test shall apply or induce a voltage whose value is 1000 v rms on each set of terminals for a duration of 7200 cycles of the applied frequency.

6.5.3 The inductance and resistance of the choke shall be measured individually and as a coupled unit, in series.

6.5.4 During module testing the input voltage to the filter and the output voltage of the filter shall be recorded at several dc output currents, including the maximum rated current. The attenuation of the filter verses frequency shall be computed.

6.6 High Potential Testing

These tests are to be conducted for a minimum of one (1) minute at 60 HZ between the designated points and the module ground or frame. Actual leakage currents are to be monitored and recorded.

6.6.1 All control circuits shall pass a hi-pot test to frame (ground) of 600 V ac rms. The control circuits shall be connected to ground during high potential testing of the power circuitry.

6.6.2 AC terminals - 2500 V, rms.

6.6.3 DC terminals - 2500 V, rms.

6.6.4 A high potential test shall be performed on the inductor. The test shall be at 60Hz for one minute between each set of coils and between the coils and the core. These tests shall be performed at 2,500 Vrms.

6.7 Acceptance

For purpose of warranty under an order for these power supplies, final inspection (acceptance) is defined as the successful completion of acceptance tests at Brookhaven to substantiate the compliance of the modules with this specification. Final acceptance shall be completed within twelve (12) months after receipt of the units at Brookhaven. The Seller will be notified of the test dates and may have a representative present to witness the tests. The Seller will be held responsible for the contracted performance of the modules produced and delivered to Brookhaven.

6.7.1 Final acceptance testing at Brookhaven may include all of the following:

6.7.1.1 Hi-pot testing
6.7.1.2 Full current heat run
6.7.1.3 Interlock, overload and protection circuits
6.7.1.4 Transient response time
6.7.1.5 P.S. controls
6.7.1.6 Output noise

7.0 Quality Assurance and the Responsibility of the Seller

7.1 The Seller shall furnish a manufacturing plan and acceptance test procedures for approval by Brookhaven. Approval by Brookhaven shall not release the Seller from his responsibility for conceptual design, manufacturing, or any other mistakes committed in the fabrication of the power supplies.

7.2 All purchased articles from subcontractors or manufacturers released for inclusion in this power supply shall be clearly identified to indicate conformance to Seller's receiving inspection.

7.3 All elements of this equipment shall be covered by a guarantee against material and manufacturing faults. The Seller shall specify in detail the guarantee period and its provisions in his proposal. The guarantee period shall be for a period of at least two (2) calendar years from the final acceptance test date.

7.4 These quality assurance requirements are in addition to the following quality assurance requirements which will be found in Brookhaven document BNL-QA-101, attached to the purchase order. The following sections apply: 3.1.2, 4.1, 4.3, 4.4, 4.4.2, 4.4.4, 4.5, 4.6, 4.7, 4.7.1, 4.10, 4.10.1, 4.10.2, 4.10.3, 4.10.5, 4.13, 4.16, 4.18, 4.19 and 4.21.

7.5 Traveler sheets shall follow each piece of equipment through production. These sheets shall document critical processes and settings for each article and shall serve as a history of its production. Copies of these travelers shall be supplied to Brookhaven.

7.6 Only calibrated test equipment shall be used. Copies of the test data sheets shall include lists of the instruments used to perform the tests and the calibration due date of each instrument.

7.7 The Seller shall establish those controls and processes necessary to ensure uniformity of all deliverable articles. All controls, inspections, tests and quality provisions established during development and pre-production tests shall be indicated on the applicable drawing and shall be performed on each deliverable article.

7.8 All units and parts of this equipment shall be properly packaged and delivered in an undamaged condition to BNL. All water circuits shall be blown free of any water prior to packaging to prevent damage during shipping or storage under freezing conditions.

8.0 SPECIFICATION DATA SHEET

8.1	Input Voltage 3 phase……	60 Vrms, +10 %, -5% per bridge
8.2	Configuration……	12 pulse two full wave bridges in series
8.3	Output Voltage……	0 to 178 VDC, max.
8.4	Maximum Time delay in SCR triggering circuitry…	1 microsecond
8.5	Maximum time jitter in high level SCR triggers…….	+/- 0.5 microseconds
8.6	SCR hard fire pulse width: range……	120° ; 160°
8.7	Balance of Inductance and Capacitance of each output terminal to ground……	1%
8.8	Output Current……	1600 amps dc
8.9	Passive Filter Inductor Resistance……	<2 mOhm
8.10	Passive Filter 3 dB point……..	100 Hz

8.11 Passive Filter Rolloff…… 12 dB / Octave

8.12 Output Voltage Ripple
(sum of all subharmonics)……. < 3 % of fundamental
Total……..… < 0.66% of VDC rated 0 to 10 KHz
< 0.1% of VDC rated 10 KHz to 1 MHz

8.13 Maximum Size (H x W x L)…… 6′ x 4.5′ x 7′

8.14 Ambient Air Temperature…….. 10 to 40 C

8.15 Maximum Inlet Water Temperature…… 40 C

8.16 Maximum differential water pressure…… 50 psi

8.17 Maximum Water Flow…… 10 GPM

8.18 Water Resistivity…… 2 Meg Ohm-cm

8.19 Maximum Humidity…… 99 %

8.20 Electrical Load…….. 0.05 henries, 0.06 ohms

8.21 Maximum Floor Loading…… 150 Lbs / ft^2

8.22 Filter Capacitor discharge Time Constant…… < 30 seconds

SELLER DATA SHEET

The information requested on this sheet shall be supplied with all proposals for Specification CSN 0256

I Module Documentation

preliminary drawings
block diagram
explanation of operation
preliminary production schedule

II Power semiconductors

Bridges

type, mfg....._____

number ....._____

PFV / PIV Rating....._____

Current Rating....._____

Cooling-gpm....._____

Expected Tjmax ....._____

Over-Voltage Protection Devices....._____

FWD

type, mfg....._____

number ....._____

PIV Rating....._____

Current Rating....._____

Cooling-gpm....._____

Expected Tjmax ....._____

III. **Transducers**

CT

type,mfg....._____

Accuracy....._____

PT's

type,mfg....._____

Accuracy....._____

IV. **Passive LCRC filter**

Inductor

Inductance……_____

Resistance……_____

Current Rating……_____

Cooling (gpm)……_____

Coupling Coefficient……_____

Capacitors

Capacitance (each branch)….._____

Manufacturer……_____

Voltage rating……_____

Fusing……_____

Damping Resistor

Resistance……_____

Wattage……_____

Cooling Requirements……_____

Electrical Schematic:
Bode Plot:

V **Triggering Circuit Requirements and Characteristics**

Expected Time delay……. _____

Expected Jitter……. ._____

VI. **Total weight of module**……_____

VII. **Dimensions (H x W x L)**……..._____

VIII **Estimated heat rejected**

air……. _____

water…… _____

IX. **Water Requirements**

general cooling water specifications

water flow (gpm)……. _____

quality of water…… _____

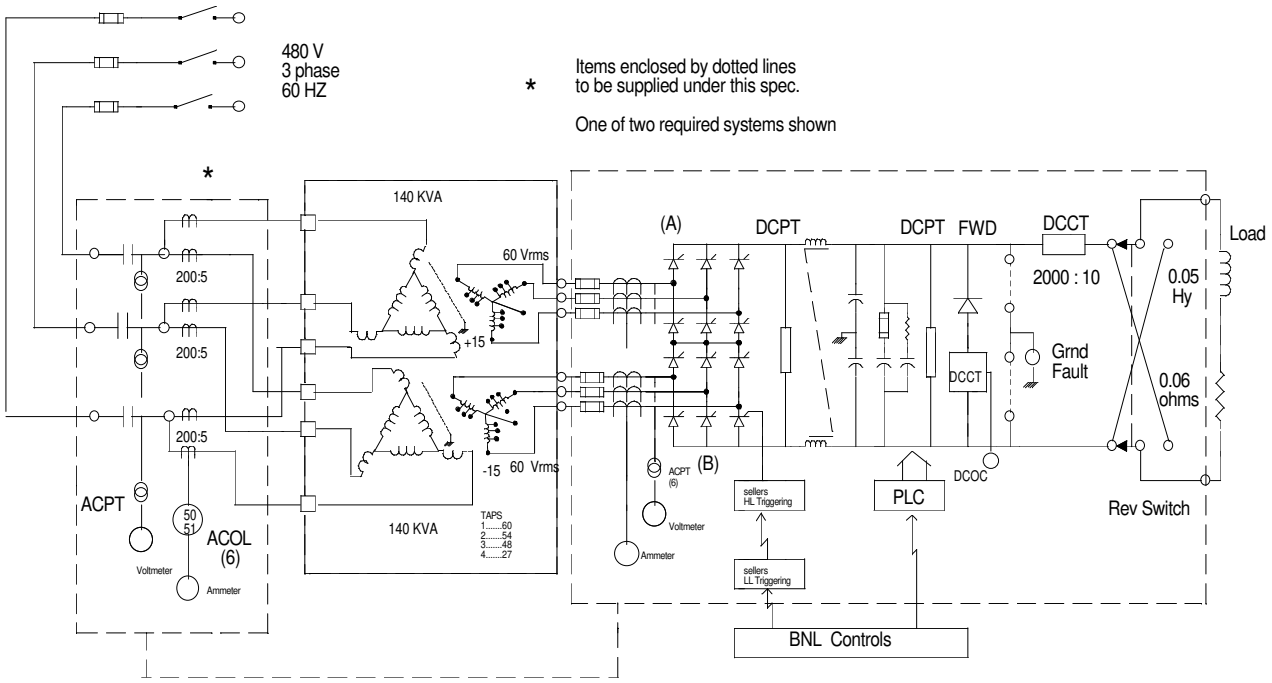
conductivity of water…….. _____

metals exposed to water ……. _____

X **Expected Delivery Time ARO**..... _____

XI Detailed list of Seller's experience with similar modules, including ratings, equipment delivered, dates shipped, and appropriate references.

XII **Exceptions to the Specification:**



One line diagram of the STAR Pole
Tip Trim Power Supply

FIG. 1

STAR Magnet Electrical Connections

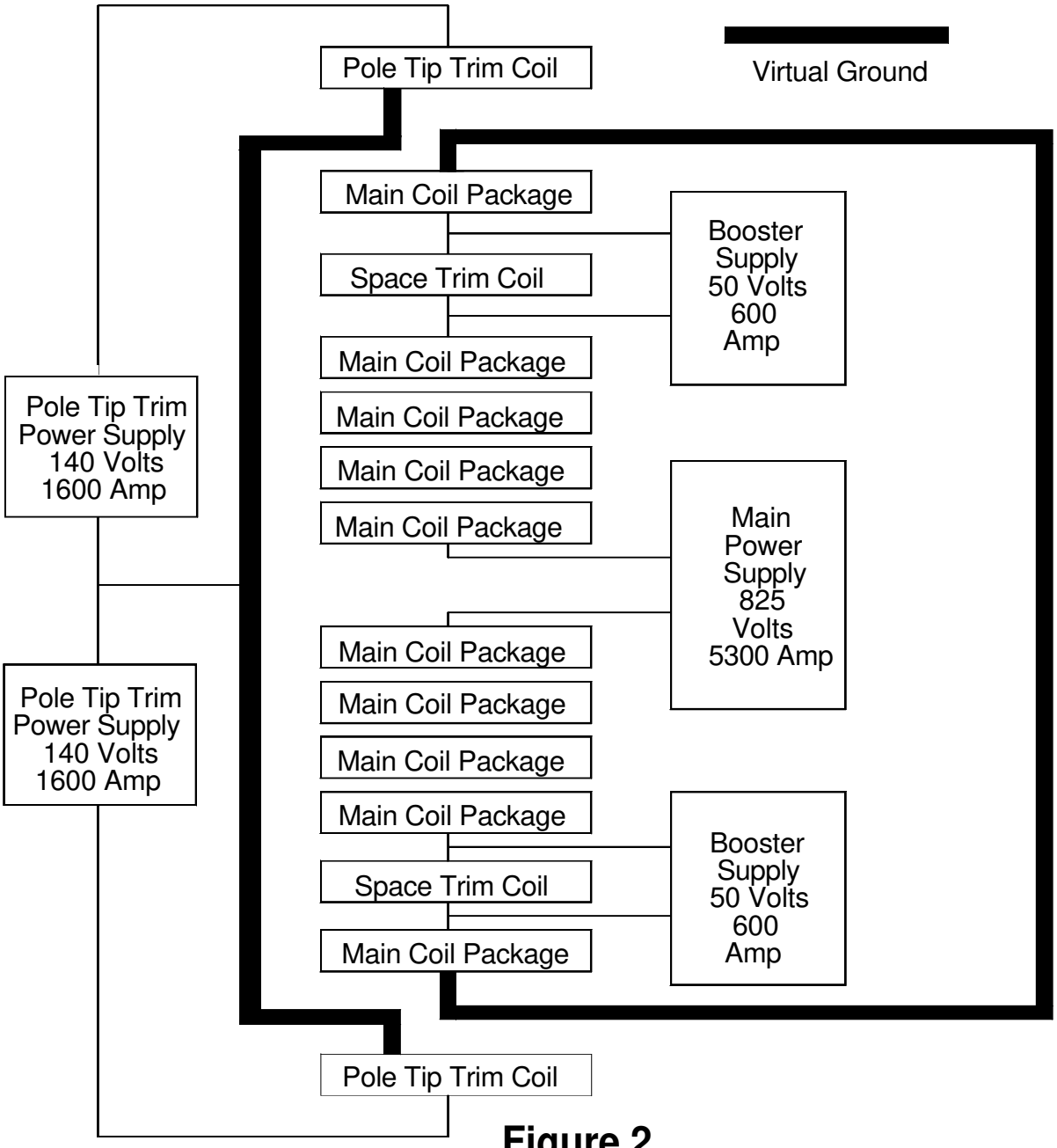


Figure 2