Jefferson Lab

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SPECIFICATION NO:
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TITLE: Hall D Pair Spectrometer Magnet Power Supply Specification

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1.0 INTRODUCTION

This specification defines the requirements for a 100 parts per million (ppm), current regulating power supply to be used to energize a dipole magnet.

There shall be:

1 ea. Power Supply – 55 Kw, 1375 A @ 40 V floor mounted, water cooled

This 100 ppm (of full Scale Output) power supply shall be built to meet Jefferson Lab specifications. Delivery requirements of this power supply shall be as called out on associated procurement documents.

2.0 DEFINITIONS

2.1 **Warm-Up**

Unless stated to the contrary, all specifications apply after a maximum warm-up period of one hour at 50% of maximum rated power and nominal AC line input.

2.2 **Static Load Regulation**

The variation in output current that results when the output load (magnet) impedance varies slowly over time is due primarily to changes in the temperature of the load.

2.3 **Static Line Regulation**

The variation in output current that results when the input line voltage is varied slowly from nominal value to either minimum or maximum specified values while all other operating parameters are held constant.

2.4 **Thermal Regulation**

The variation in output current after rated warm-up period, measured at any selected load point, during steady state conditions of all external operational and environmental parameters.

2.5 **Stability (Drift)**

The variation in output current over a 24 hour period after rated warm-up period, measured at any selected load point, during steady state conditions of all external operational and environmental parameters.

2.6 **Dynamic Line Regulation**

The variation of the current, that ultimately disappears due to the regulator, after an abrupt increase or decrease of the nominal line voltage, while load conditions are held constant.

2.7 **Periodic and Random Deviation (PARD)**
The variation of the output current which is the sum of current deviations including frequency variations, hum, noise, phase imbalance and spikes, while all external operational and environmental parameters are held constant.

2.8 **Envelope of Uncertainty**
The envelope of uncertainty describes the total effect of all contributions to output current error. It consists of the sum of static load regulation, static line regulation, dynamic line regulation, thermal regulation, PARD and stability.

2.9 **Personnel Safety System (PSS)**
An external control system tasked with protecting personnel. The power supply is required to provide certain interfaces to this system. Also, the parts and circuits of the Power Supply associated with protecting Personnel from electrical and other hazards associated with operation of DC power supplies.

3.0 PERFORMANCE EXPECTATIONS

3.1 This power supply shall have a total Envelope of Uncertainty (see definition in section 2.8) of 100 parts per million (ppm) of full scale output.

3.2 This power supply will be used to power the Pair-Spectrometer dipole magnet in a high energy photon accelerator being built in Newport News, Virginia for the Department of Energy. The dipole magnet typically has a low resistance and inductance.

3.3 These power supplies will be remotely controlled and will run unattended for long periods of time in outlying buildings, so very reliable operation is necessary.

3.4 Because of the high cost associated with an idle accelerator, suitable diagnostics and quick, modular repair features shall be incorporated into the power supply to minimize the time required to repair a faulty unit.

3.5 Environmental Control: Power supplies must be able to operate with ambient air that is less than ideal, for instance, as when a large door is open to the outside at the same time that the building exhaust fans are on. Usual building temperature ranges from 5 C to 44 C, with a nominal temperature of about 28 C.

3.6 The vendor shall furnish all labor, equipment and materials, and perform all work necessary, to design, prepare drawings and manuals, manufacture, assemble, prepare test procedures, factory test, prepare and load for shipment, and deliver, F.O.B., Jefferson Lab, Newport News, Virginia, the power supply described here.

3.6.1 At Jefferson Lab's option, the vendor shall hold a design review to be attended by representatives from Jefferson Lab, for approval of the vendor's proposed plan for demonstrating compliance to the specifications contained herein.

3.6.2 Vendor shall meet all design criteria and test criteria as set forth in this specifications document.

4.0 POWER SUPPLY SPECIFICATIONS

4.1 **Input Requirements**

4.1.1 The power supplies shall be designed to operate from Jefferson Lab's nominal 480 volt, 3 phase, 3-wire + safety ground wire (no neutral connection), 60 Hertz, sources having the following characteristics:

Voltage: 480 volts + 10%

Line Imbalance: + 5%, line-to-line

Frequency: 60 Hz, + 3 Hz

Each power supply will have a single source of AC voltage with the above voltage characteristics. All voltages required for control or operation must be derived from this single 480 VAC 3-phase input.

4.1.2 AC Disconnect

4.1.2.1 The incoming AC line side of the power supplies shall have a manually-operated disconnect switch. Opening the main disconnect switch shall remove *all* power, including control power, from the supply. This switch does not need to provide fault protection.

4.1.2.2 The disconnect switch shall have its contacts in a separate enclosure such that no incoming AC voltages are present inside the serviceable parts of the Power supply when the switch is in the "OFF" position.

4.1.2.3 The main disconnect switch shall have an operator lever with provisions for padlocking it in the "OFF" position.

4.1.2.4 The main disconnect switch and other 480 volt components shall be mounted and/or covered so that exposed terminals or conductors at this potential are minimized with the front or back doors open.

4.1.2.5 Inrush protection shall be provided such that the line current shall not exceed normal full load current during turn-on.

4.1.2.6 Terminals for connection of AC line power shall be sized conservatively for the required cable fittings. Cabling used for AC line power shall be of 500 MCM type cable with maximum current carrying capacity of 600 Amps per cable. Cable fittings must accept type 500 MCM crimp type (2 hole NEMA lugs for 1/2" bolts on 1 ¾" centers).

4.1.3 Main Contactor

4.1.3.1 A three phase, 3-pole, contactor(s) shall be used to turn the 480 volt power to the main transformer(s) on and off. An actuator operated circuit breaker is not acceptable.

This contactor(s) shall be operated by a nominal 115 VAC, 60 Hz, derived from the main power input.

4.1.3.2 Monitoring Input AC Power

a. A set of 4 contacts mechanically-linked to the Main Contactor(s) shall be provided to monitor the status of the Main Contacts.

b. The auxiliary contacts must meet IEC 60-947 specifications.

c. Two of the contacts will be used for PSS system and 2 of the contacts will be used for status and control. The use of the auxiliary contacts for PSS is outlined in Appendix I, Item 5.

d. The 2 contacts used for status and control shall be of the normally open type. The 2 contacts used for PSS shall be of the normally closed type.

4.1.4 If needed to match ratings to loads, power transformers shall be provided with up to 3 tap settings to provide adjustable output voltages and currents. Desired tap settings are shown in Appendix II.

4.1.5 This section is intentionally omitted.

4.1.6 See Section 10.6 for EMI/EMC specification

4.1.7 Input connectors and layout shall follow mechanical specifications as described under Mechanical design

4.1.8 The Power Factor for the Power supply should be 90% or better at full rated power and line voltage within +/- 3% of nominal.

4.2 **Output Requirements**

4.2.1 The output of the Power Supply will be a constant DC current source that will follow a command set point. The output DC voltage and current requirements are shown in Appendix II.

4.2.2 The complete power supply shall meet the specified performance requirements for both local and remote control operation. The current set point can be set locally or remotely.

4.2.3 The Power supply shall be rated to run continuously (24 hours per day) in an ambient temperature range of 5 C to 44 C (10% to 98% humidity, non condensing).

4.2.4 The power supply output shall be regulated for the following modes of operation (remote control operation shall disable local control modes except for the off button).

4.2.4.1 “Local” current regulation: Current regulate the power supply output from an internal reference source supplied by the vendor, adjustable from the front panel of the power supply.

4.2.4.2 “Remote” current regulation: Current regulate the power supply output from external digital commands supplied by Jefferson Lab. (See Attachment 1 for details of remote digital control interface.)

4.2.5 This power supply shall regulate satisfactorily while operating into loads having the following characteristics:

a. Pure resistance: _0.03_ m-ohms 55 KW (test load)

b. The DC voltage and current output requirement for this supply is shown in Appendix II.

4.2.6 The envelope of uncertainty due to worst cases of the following tolerances shall be less than 100 ppm of F.S. current output.

a. +10% Static and dynamic line variations

b. +10% Load resistance variation at 50% of full scale current output.

c. 5 - 44 DEG C Ambient thermal variation

d. 57-63 Hz Frequency variation

e. +5% Line to line voltage imbalance

f. 24 hour stability (drift)

4.2.7 The output current shall be regulated within specification (see section 4.2.6) for any current value between 10% and 100% of rated output for each transformer link connection. In addition, the power supply shall be capable of furnishing controllable, smoothly variable current at any level from 5 to 100% of output rating.

4.2.8 Output current must settle to +1% of DC level within 75 milliseconds of a +2% to +10% step line change. For a step line change of +2% or less, the power supply output current shall stay within the 100 ppm envelope of uncertainty.

4.2.9 Any setting from 10% to 100% of full current shall repeat to 100 ppm of rated current when power supply is operated within the conditions of section 4.2.6, after a warm-up period.

4.2.10 The set-ability (resolution) and linearity of the external digital command word and output current shall be equal to or better than 150 ppm of rated output from 10% to 100% load while operating within the conditions of paragraph 4.2.6.

4.2.11 The calibrated *absolute* accuracy from the digital command to the output current shall be equal to or better than 150 ppm of rated current at nominal input line, static load and at 25 DEG C ambient temperature.

4.2.12 The output terminals shall “float” electrically with respect to earth ground and chassis ground. The power supply shall be dynamically stable when neither terminal of the output or the load is grounded. In the intended operation the ground point will be centered about the load.
The floating output shall be able to withstand a hi-pot test of up to 1.5 times the rated output voltage from the output terminals to chassis ground for 1 minute with leakage current less than 200 micro-amps.

4.2.13 While operating in local or remote current regulation mode into a resistive load, the envelope of uncertainty of the average output current must be less than 100 ppm of full scale output.

4.2.14 The output of the power supply shall have a freewheeling diode connected across its output. This diode and its heat sink shall be sized to carry full output load current.

4.2.15 The control loops shall be designed to be dynamically stable when operating into the specified magnet loads or when driving a resistive load for test purpose.

If necessary, changing a jumper or actuating a switch to meet the above requirements are acceptable methods of selecting loop compensation as long as a circuit board need not be withdrawn to do so. The use of a potentiometer is not acceptable.

4.2.16 The output ripple voltage must not cause the output current to exceed the total envelope of uncertainty. Vendor must provide ripple mitigation scheme as part of the design proposal.

4.2.17 Intentionally left blank

4.2.18 Power losses from input to output must not exceed 15% of the rated output power of the supply.

4.2.19 Terminals for connection of DC output power shall be sized conservatively for the required cable fittings. Cabling used for DC output power shall be of 500 MCM type cable with maximum current carrying capacity of 600 Amps per cable. Cable fittings shall be of type 500 MCM crimp type (2 hole NEMA lugs for 1/2” bolts on 1 ¾” centers).

4.3 **Current Feedback and Monitor Devices**

4.3.1 The power supply shall have a primary high-precision low-drift transducer for providing feedback to the regulator, and input to the remote monitoring system (See Section 4.8.8). The transducer shall be designed, mounted and shielded so that the readout signal stays within the specified limits when the power supply stray magnetic fields are present and the environment changes, as specified in section 4.2.6. .

4.3.2 The preference for the primary transducer is of a zero-flux DC current type. The transducer must have 100 ppm stability and a wide bandwidth. The specific transducer model used in these power supplies shall be subject to approval by Jefferson Lab to insure that a well proven unit is used. A resistive shunt is not acceptable for the primary current measuring device

4.3.3 There shall also be a secondary method of monitoring the current such as a lower precision transducer or shunt. This device shall have at least 0.5% accuracy and be capable of furnishing a *buffered* analog signal to a BNC connector on the front panel as well as to a 3 1/2 digit panel meter. This signal may have one terminal referenced to control (chassis) ground.

4.3.4 (Intentionally left blank)

4.3.5 (Intentionally left blank)

4.4 **Soft Start**:
The system shall be equipped with a main AC contactor coordinated clamping circuit which will limit the output turn-on surge voltage to less than 5% of the rated output voltage, regardless of the reference voltage (the main power supply contactor may be turned on in the remote control mode with the full scale command word already present). The soft start circuit must limit the AC inrush current to less than 10% of the maximum steady state current.

4.5 **Ramped output**:
There shall be a ramp control which allows adjustment of the rate of rise and fall of the output current from 5 Amps per second to 25 Amps per second. This adjustment by means of a potentiometer located on the regulator board is also acceptable.

4.6 The power supply's regulation controls must be critically damped, avoiding undershoot or overshoot during ramping.

4.7 The Box Supplies must have "Remote" and "Local" control abilities as outlined in Section 4.8 and 4.9.

4.8 **Remote Control Mode**

4.8.1 The remote interface shall comply with the serial link hardware and software protocol detailed in Attachment 1.

4.8.2 Remote monitor and control via the RS485 serial link will be the default mode at Jefferson Lab, thus the unit must default to the remote mode upon power up.

4.8.3 The following controls must be provided while in Remote Mode

a. Power Supply Start (Energize output of Box Supply)

b. Power Supply Stop (De-energize output of Box Supply)

c. Reset Faults

4.8.4 The output current shall be controlled by a high precision stable DAC which can be remotely set through the RS485 link, as outlined in Section 4.2.4

4.8.5 The output current shall be monitored by a high precision ADC which can be read back through the RS485 serial link. The ADC shall get its input from the buffered output of the main transducer, which is used to measure the output current and provide a feedback signal.

4.8.6 Any microprocessor based controller used in the power supply must have a watchdog circuit. If the microprocessor fails to operate properly, the watchdog circuit shall set a fault indicator with an option to turn off the main contactor if required for Power Supply protection, or so desired by Jefferson Lab.

4.8.7 All status, fault, control, interlock, and diagnostic information shall be available remotely via the RS485 serial link.

4.8.8 The following Diagnostic Read backs must be made available through the RS-485 link:

a. Output current

b. Output current DAC set point

c. Output voltage

d. Regulator Thermal block temperature (if used)

e. Control Loop Voltages

f. Redundant current read back or reference current

g. Internal power supply voltages

h. Status of all internal and external interlocks

4.9 **Local Control Mode**

4.9.1 The Power Supply shall have a Local/Remote switch on the front panel that activates/de-activates the local control mode.

4.9.2 When in the Local control mode, the Power supply must ignore any commands from the Remote interface.

4.9.3 The following controls will be provided on the front panel of the power supply for operation in the Local mode:

a. Power Supply Start (Energize output of Box Supply)

b. Power Supply Stop (De-energize output of Box Supply)

c. Reset Faults/Interlocks

d. Reset micro-controller

4.9.4 The output current set point of the Power Supply must be controllable via a controller on the front panel as outlined in Section 4.2.4

4.9.5 All status, fault, control, interlock, and diagnostic information shall be accessible via the front panel display.

4.9.6 **Emergency Stop:**
An Emergency Off - red, "mushroom" style, twist to reset switch shall be provided in an easily accessible part on the front and rear of the power supply. Activating the Emergency switch must instantly de-activate the Main Contactor, latch a fault, and indicate to the remote communication and locally to the front panel. (See Appendix I for further details on Emergency Stop interlock)

5.0 GROUNDING

5.1 **Ground Fault Detector**

5.1.1 The power supply shall be equipped with an adjustable ground fault detector that will turn off the output of the power supply when a fault is detected. The adjustment on the ground fault indicator must have a means of indicating the current at which the detector will trip and shall be adjustable from 0.01 to 1.0 ampere. There must also be a means of reading the ground fault current.

5.1.2 Since in Jefferson Lab's intended applications, neither the "+" or "-" output lead of the power supply may be referenced to earth ground, the ground detector must detect currents of *either* polarity. Ground fault interlock indications must be available as specified in Appendix I.

5.1.3 Protection circuits that limit the maximum ground fault current (such as fusing) shall not cause this interlock to be disabled, following their activation or clearing.

5.2 A ground pad shall be provided for an external ground connection to the chassis of the power supply. This pad shall be located close to the AC input connections of the power supply.

5.3. **Safety Grounding.**
Fully visible, manual-grounding devices (ground hooks) shall be provided to render the capacitors safe while they are being worked on for power supply outputs over

50 volts. Grounding points shall be clearly marked, and caution must be used to prevent transferring charges to other capacitors.

5.4 **Ground Hooks.**
All ground hooks shall:

a. Have conductor terminations crimped and soldered.

b. Be connected such that impedance is less than 0.1 ohms to ground.

c. Have the cable conductor clearly visible through its insulation.

d. Have a cable conductor size of at least #2 extra flexible, or in special conditions, a conductor capable of carrying any expected current.

e. Be in sufficient number to conveniently and adequately ground ALL designated points.

f. Be grounded and located at a normal entry way when secured, in a manner that assures that they are used before entry. When secured in its normal storage location, the ground stick must close an interlocked switch that indicates that the grounding hook has been safely returned to its normal position.

5.5 In equipment with stored energy in excess of 5 Joules, a discharge point with impedance capable of limiting the current to 500 amperes or less should be provided. This discharge point shall be identified with a yellow circular marker with a red slash and shall be labeled “HI Z PT” in large readable letters. A properly installed grounding hook shall first be connected to the current limiting discharge point and then to a low impedance discharge point (less than 0.1 ohm) that is identified by a yellow circular marker labeled “LOW Z PT”, and remain connected this way so that the energy is discharged. The grounding hooks shall be left on the low-impedance points during the time of safe access. The low impedance LOW-Z points and the HI-Z current limiting points shall be provided as needed.

6.0 INTERFACES

6.1 The supply shall have capability of monitoring 3 contact closures that interface with external shunt circuitry. Opening of any of these contacts must turn off the output of the power supply.

6.2 The supply shall have capability of monitoring 2 contact closures for thermal interlocks on the magnet loads. Opening of any of these contacts must turn off the output of the power supply.

6.3 See Attachment 1 for interface with the communications and remote controls to the power supply.

6.4 See Appendix 1 for interface with external PSS hardware

6.5 Intentionally left blank

7.0 DIAGNOSTICS

7.1 The following interface signals, controls, and indicators shall be provided:

a. Status Indicators:

- Control Power on
- Main contactor closed
- Local/Remote mode
- Ready, but main contactor open

b. Fault Indicators:

All internal and external fault indications generated by the supply shall be returned to the control system and also indicated by latched front panel indicators. Provision for 12 user-defined external interlocks shall also be provided that latch and indicate both on the front panel and via the control system read back. A “reset out” signal (isolated opto-isolator or momentary contact closure) shall be provided to allow resetting of external devices via the same pushbutton and control system command used to reset the internal fault latches.

7.2 All status, fault, control and diagnostic information shall be available from the front panel display. The panel may be menu-driven.

7.3 Indicator lights shall be of the LED type and shall be mounted and properly labeled on the front panel of the power supply.

7.4 All analog monitoring signals shall be scaled, buffered, and referenced to a common control (chassis) ground.

7.6 For transistor banks or paralleled devices, there shall be the following means of indicating when one of the devices has failed:

There shall be an interface status bit indicating when one or more devices have failed as well as local flags, such as indicating fuses, which help to rapidly determine the damaged power device.

7.7 Diagnostics for all AC voltages and currents shall be made available using PT's and CT's to a diagnostics panel. CT's shall also be used on power converter output leads.

7.8 The DC output over-current protection shall be provided by an easily adjustable optical meter relay or equivalent device.

7.9 A 3 1/2 digit panel meter shall be provided to monitor the power supply output voltage. This meter shall have over-voltage protection. Accuracy and linearity of readout shall be +1%.

7.10 A 3 1/2 digit panel meter shall be provided to monitor the power supply output current from the secondary current measuring device. Accuracy and linearity of readout shall be +1%.

7.11 (Intentionally left blank)

7.12 It is preferred that there are no summed faults in the indications.

8.0 MECHANICAL

8.1 The power supply will be rated for indoor installation. The power supply shall be cooled using Low Conductivity Water (LCW) as defined in Attachment 2 and Appendix IV.

8.2 The power supply shall be housed in sturdy metal enclosures. Eyebolts shall be furnished for lifting the unit. Free standing power supply cabinets shall be fabricated such that a fork truck may be used to move them without damage. A fork truck or palette jack must be able to operate from the front, back or sides of the power supply cabinets, in order to lift and move them.

8.2.1 Maximum dimensions of the power supply shall not exceed 84 inches high, 108 inches wide, and 60 inches in depth, inclusive of eyebolts and top-mounted disconnect switch. Expected Power supply footprints are shown in Appendix IV.

8.3 AC and DC connections:
Power supplies shall have the AC entry at the top on one side of the enclosure while the DC connections entry shall be at the top, rear on the opposite side of the AC entry. Alternatively, the AC may enter directly into the disconnect switch enclosure from the side or rear of that enclosure.

8.4 All water fittings and hoses shall be as specified in Attachment 2.

8.5 (Intentionally left blank).

8.6 All parts inside the enclosure shall be easily accessible by removing protective, screwed-in-place covers.

8.7 All operating and indicating devices, except for the disconnect switch, shall be front, flush panel mounted.

8.8 The vendor shall install all connectors for making the external connections, and provide mating connectors for interfaces, except for AC input and DC output.

8.9 The power supply shall be painted with a rust-resisting primer and a finish coat of semi-gloss enamel, color number 25488, light blue, light texture. The power supply finish shall conform to Federal Standard 595B.

8.10 The power supply shall be designed to continuously operate in an ambient temperature range from 15 C to 44 C, relative humidity range 10% to 98% non-condensing at an altitude of 0 to 500 feet above sea level.

8.11 All bus bars shall be tinned or plated to prevent corrosion.

8.12 The power supply shall have a nameplate indicating the input requirements, output rating, total weight, serial number, water requirement, and vendors-type number. The nameplate must be on the front of the Power Supply.

8.13 Instruction plates showing any required link positions for all specified transformer connections shall be installed in an easily visible location on the back of rack mounted power supplies. These instruction plates shall also indicate other required switch positions for the various specified connections.

8.14 All electronic modules are to be plug-in units.

8.15 Blind fasteners shall be used wherever possible, especially for the lugs and electronic assemblies that may require service.

8.16 “Ovenizing” of an entire card cage is not acceptable because it makes access for trouble shooting too difficult.

8.17 Acoustic emissions from the power supply shall be minimized.

8.18 There shall be a bimetallic “Klixon™” style over-temperature switch associated with each power heat sink. These switches shall be connected into a power supply interlock system so that the supply will shut down if one or more of the switches open. The status of the interlock must be available to the remote monitoring system and on the front panel display.

8.19 (Intentionally left blank).

8.20 If used, power transistor banks shall be hinged or fabricated in some way to make access quick and easy for device replacement.

8.21 Terminal blocks for external connection of AC line power shall be sized conservatively for the required cable fittings (See 4.1.2.6). Terminal blocks for DC output current shall be sized adequately for the required cable fittings (See 4.2.19). Terminal blocks shall be firmly supported to withstand the installation of large cables. DIN rail mounted terminal blocks are not acceptable for this application.

8.22 There shall be adequate natural convection or forced air flow to provide cooling for low level electrical and electronic components. If fans are used, they shall be 115 VAC units.

8.23 Top level mechanical assembly drawings will have to be submitted at the Design Review as outlined in Section 3.6. Jefferson Lab technical representative must have ability to review and make recommendations on mechanical placement of critical components.

9.0 SAFETY AND INTERLOCKS

Interfaces for External Interlocks

9.1 An interlock system shall be installed such that any interruption in the electrical continuity (break) of an interlock chain or, alternatively, failure to have a summation of satisfied individual interlocks, removes power supply enable signals and de-energizes the Main Contactor. (See Appendix I for interlock specifications)

9.2 Interlock devices, such as door switches, and all external interlock circuits shall be operated on 24 VDC. (i.e. 24 VDC must be applied through the contact closures.)

9.3 Jefferson Lab will provide external interlock contact closures related to magnet over temperature, accelerator safety system, and related equipment. (See Appendix I)

9.4 There shall be two external interlocks related to external PSS equipment. (See Appendix I)

9.5 Door interlocks similar to micro switch model 2AC6, shall be provided and have provisions for defeat with automatic reset on closure of the doors. The door interlocks should be part of the power supply safety system interlock chain. (See Appendix I for Door interlock specifications) There shall be a redundant door interlock system for any door which allows access to the output terminals or

potentials in excess of 50 VAC/DC. The intent of this requirement is to provide dual, redundant interlock control for personnel safety.

9.6 The main rectifier transformer shall not require immersion in liquid for cooling and shall be designed and mounted in such a way that it can easily be replaced without major disassembly of other components.

9.7 The cataloged maximum repetitive peak reverse and forward break over voltage rating of any AC Line commutated Power Switching cells employed shall be at least 2.5 times the maximum applied voltage at 10% high line input.

9.8 Fuses shall not be used as a primary protection on any AC line commutated Power switch element. Failure of any power leg through a switching element shall be detected by a phase imbalance circuit and result in a power supply main contactor trip before other damage can occur. The phase imbalance circuit shall trip when phase current imbalance exceeds 5% of line current. Trip setting shall be readily adjustable between 2% and 10% by the user.

A current phase imbalance fault shall shut supply down, activate a local front panel indicator, and provide a signal to the remote digital interface. If multiple phase imbalance detectors are used, each unit should latch and have independent indication to the control system.
A voltage phase imbalance fault shall shut supply down, activate a local front panel indicator, and provide a signal to the remote digital interface

9.9 For personnel safety, while trouble shooting any power switching elements, there shall be switcher firing pulse transformers located at the switching elements so that the low level pulse generation circuitry is isolated from the high power circuitry.

9.10 Any power switching components shall have suitable snubber circuits to protect from voltage spikes and to reduce the EMI generated.

9.11 Each terminal block, shall have a minimum of 20% spares for use by Jefferson Lab.

9.12 (Intentionally left blank)

9.13 480 Volt, three phase wiring shall be kept separate from all other wiring. The design must be such that Jefferson Lab input 480 VAC wiring can be run directly to the input side of the lockable disconnect switch, so that when the disconnect switch is “off”, there are no exposed 480 VAC in the unit.

9.14 Any plug wiring shall have adequate wire lengths for ease of access to the pins.

9.15 Intentionally left blank.

9.16 If the safety interlock chain is tripped, the output voltage (Vout) should go to -5V < Vout <5V in less than 100 milliseconds when connected to a resistive load.

9.17 **Safety Considerations for Capacitors:**

Automatic Discharge: Permanently connected bleeder resistors shall be used for high voltage capacitors. Capacitors in series shall have separate bleeder resistors. Automatic-shorting devices that operate when the equipment is de-energized or the enclosure is opened should be used. The time required for a capacitor to discharge to safe voltage (50 volts or less) shall not be greater than the time needed for personnel to gain access to the voltage terminals. Bleeder resistors sizing must conform to NEC Article 460.

Fusing. Capacitors used in parallel should be individually fused when necessary to prevent the stored energy from dumping into a faulted capacitor, and causing the capacitor case to fail. Care must be taken in placement of automatic-discharge safety devices with respect to fuses. If the discharge will flow through the fuses, a prominent warning sign must be placed at each entry indicating that each capacitor must be manually grounded before work can begin.

9.18 Control and other auxiliary power shall come through a separate control power transformer which is connected to the load side of the 480 V line disconnect switch. When the disconnect switch from the 480VAC line is in the off position, the control power must be able to be energized from an external 115VAC molded case plug. Control power must have a separate fuse or fast acting circuit breaker. Presence of control power shall be indicated by a pilot light on the front panel. There shall be 24 Volts DC @ 3 Amp control power available at a terminal strip, in the rear of the enclosure, for Jefferson Lab use.

9.19 A Voltage Verification Unit (VVU) shall be used on the load side of the disconnect switch to ascertain that the disconnect switch has removed 480 Volt power to the inside of the Box Supply. The VVU shall monitor Line-to-Line and Line-to-Ground voltages. The VVU is used to verify that 480 VAC has been disconnected by actuation of the disconnect switch, making it safe to enter the power supply enclosure. The VVU must have a meter, LED's and selector switch to choose between line-to-line and line-to-ground voltage measurements. (A copy of typical Jefferson Lab VVU schematic and requirements is provided in Appendix III)

10.0 QUALITY ASSURANCE AND STANDARDS

10.1 The vendor shall assume full responsibility for the power supply to conform to the best engineering and manufacturing practices. In all respects, except where

specifically mentioned otherwise, equipment shall conform to, and electrical tests shall be conducted in accordance with, the latest applicable standards of:

a. American Society of Testing Materials

b. American Standards Association, Inc.

c. Institute of Electrical and Electronics Engineers

d. National Electrical Manufacturers Associations

e. Underwriters Laboratories, Inc.

f. National Electrical Code

10.2 Intentionally left blank.

10.3 The power supply shall be completely assembled and ready for operation upon connection to AC power, output load, and cooling water.

10.4 Interchangeable, easily removable subassemblies shall be used where practical, to provide a maximum flexibility of use and a minimum time loss for repairs.

10.5 Each type of power supply shall have a MTBF rating of greater than 40,000 hours as determined by MIL-STD-217D for equipment with ground benign environment or there shall be sufficient field experience with the design type to infer that the unit will meet the above MTBF rating.

10.6 For frequencies greater that 7200 Hz, this power supply shall meet the FCC Class A specification for allowable conducted line noise for commercial equipment. Noise generated by the power supply and transmitted to the AC line shall conform to MIL-STD-461 and FCC Class A Industrial devices.

10.7 All control and interlock relays shall be hermetically sealed or be of the sealed plastic-case variety and shall be socketed. Relays shall have clamping diodes or transient absorbers which protect external equipment from transients due to solenoid fly back voltages.

10.8 All wires and terminals shall be clearly marked with identifying numbers or letters for ease in servicing.

11.0 DESIGN ACCEPTANCE CRITERIA

11.1 A factory technical contact shall be identified, who will be able to answer questions and coordinate all technical phases of the procurement with the Jefferson Lab Subcontracting Officer's Technical Representative.

11.2 Three (3) copies of a Preliminary Design Report, including proposed circuit diagrams of the power supply and drawings of the assembly and outlines must be submitted to the Jefferson Lab Technical Representative, for approval, within forty five (45) calendar days after award of contract, and prior to any construction.

11.3 When the drawings and information submitted are approved by Jefferson Lab, two copies will be returned to the vendor identified as having received such approval by being stamped and dated. Jefferson Lab will return the drawings within fifteen (15) calendar days of receipt.

11.4 Approval by Jefferson Lab of the vendor's drawings shall not be construed to relieve the vendor of any part of the vendor's obligation to meet all of the requirements of these specifications, or of the responsibility for the correctness of the vendor's drawings.

11.5 Jefferson Lab will hold a Design Review and make changes and recommendations to the proposed Designs from the vendor. The Design Review may be held at the vendor's facility.

12.0 PRODUCT TESTING AND ACCEPTANCE

12.1 **Pre-shipment Acceptance Procedures - First Article**

12.1.1 A first article test at the Vendor's factory is required to validate the performance and compliance to specifications of the power supply design.

12.1.2 The first power supply to be produced (the First Article) shall be factory tested by the Vendor according to all the procedures in Section 12.5 and the First Article Approval - Subcontractor Testing, provision E-4. This testing may be witnessed by Jefferson Lab personnel.

12.1.3 The Vendor shall notify the Jefferson Lab Technical Representative at least fifteen (15) working days before any such performance tests, so that a Jefferson Lab representative may be present when the tests are conducted.

12.1.4 Jefferson Lab may decide not to witness testing of the first article at the Vendor's factory. Within ten (10) calendar days following notification in accordance with section 12.1.3, the Jefferson Lab Technical Representative will advise the vendor if Jefferson Lab will witness the performance testing.

12.1.5 The Vendor shall supply copies of the Test Data Sheets to Jefferson Lab for inspection and approval. In the event Jefferson Lab elects not to witness the

testing, Test Data Sheets are sent to the Jefferson Lab Technical Representative and will be approved or disapproved by the Jefferson Lab Technical Representative within fifteen (15) calendar days after receipt.

12.1.6 Approval of pre-shipment test results and authorization to ship does not constitute final acceptance of the First Article or its design by Jefferson Lab. It remains the Vendor's responsibility to provide a power supply which meets all of the requirements of this specification.

12.2 **Pre-shipment Test Procedures - Production Units**

12.2.1 Before shipment, the vendor shall conduct performance tests, per the procedure of Section 12, on each assembled power supply to insure that the equipment is in full compliance with the requirements of this specification.

12.2.2 The vendor shall submit to the Jefferson Lab Technical Representative a complete Performance Test Report for the power supply within ten (10) calendar days after completion of the performance testing. This report must be approved by and authorization received from the Jefferson Lab Technical Representative before the power supply is shipped to Jefferson Lab.

12.2.3 Approval of pre-shipment test results and authorization to ship does not constitute final acceptance of the unit by Jefferson Lab. It remains the Vendor's responsibility to provide a power supply which meets all of the requirements of this specification.

12.3 **Receiving Acceptance Procedures at Destination - All Units**

12.3.1 Receiving acceptance for all units will occur after the power supply has been delivered to Jefferson Lab and the power supply has been successfully tested by Jefferson Lab according to all or part of the procedures in Section 12 and found to be in compliance with the requirements of this specification.

12.3.2 Preliminary documentation will be required in order to test units as they arrive at Jefferson Lab. With the First Article unit, the Vendor shall include one copy of a Preliminary Installation Manual and a Preliminary Operating and Troubleshooting Manual which shall provide all necessary information required by Jefferson Lab for the proper installation, operation, and remote programming of the unit. This preliminary information need not meet all of the provisions of Section 13.0 but must be sufficient in scope to permit installation and testing of the supply by Jefferson Lab personnel.

12.3.3 Receiving acceptance testing will be accomplished within forty-five (45) calendar days after receipt of each unit at Jefferson Lab. If a power supply fails initial acceptance testing, the Vendor will be notified of the outstanding deficiencies within this time. A percentage of the payment for any such unit will not be made until it has been repaired or modified by the Vendor and has successfully passed the Receiving Acceptance Testing procedure.

12.4 **Acceptance of Final Documentation**

12.4.1 The Installation Manual, Operations Manual, Trouble Shooting Manual, Software Documentation, and Final Drawing Set are an integral part of the power supply order.

12.4.2 Prior to the completion of this contract, the Vendor shall supply a Final Documentation Set consisting of those items required by Section 13.3. These items must be delivered with the final power supply unit.

12.4.3 The Final Documentation Set will be approved or disapproved by the Jefferson Lab Technical Representative within fifteen (15) calendar days after receipt. A disapproval notice will state the deficiencies in compliance with this specification which must be corrected before the Documentation Set will be approved for payment.

12.4.4 Payment for the final power supply will be withheld pending acceptance by Jefferson Lab of the Final Documentation Set.

12.5 **The following tests and inspections shall constitute the Performance Test by JLAB:**

12.5.1 Visual inspection

12.5.2 Hi-pot output for 1 minute at 1.5 times the rated output voltage. See Section 4.2.12 for specific requirements.

12.5.3 Check all auxiliary power supply voltages for proper values.

12.5.4 Test all interlocks, indicators and semaphores for proper operation.

12.5.5 Operate the power supply with a remote control station simulating computer control, and locally using front panel controls.

12.5.6 Check firing control circuitry.

12.5.7 Check power semiconductor drive.

12.5.8 Check power semiconductor voltages.

12.5.9 Check output ripple.

12.5.10 Obtain up to 80% of rated output current; measure AC line currents and voltages. Obtain up to 90% of rated output voltage.

12.5.11 Calibrate DC over current trip.

12.5.12 Trip the power supply off with various fault conditions and re-start unit five (5) times. Test must be done at half the rated output power or with power supply operating with 90% of rated output current.

12.5.13 Transducer:
Calibrate the transducer within the limits of Section 4.3. Calibration shall be obtained from an external precision shunt or transducer.

12.5.14 Linearity, Accuracy and Repeatability

a. Calibrate input reference voltage versus output voltage to demonstrate performance required for regulation according to Sections 4.2 and 4.3

b. Calibrate input reference voltage versus output current to demonstrate that performance meets requirements of Sections 4.2 and 4.3

12.5.15 (No entry)

12.5.16 Thermal Test

Monitor operating temperatures under following conditions:

Run the unit at 100% of rated output current for 24 hours into a resistive load with 25-30 DEG C ambient and 35 DEG C inlet water temperatures at a maximum pressure differential of 70 PSI. Transformer taps and other links should be set for the highest possible output voltage. Observe that power supply meets all specifications including current regulation stability requirements. Repeat the test with unit at 100% of rated output voltage. (Note: The supply will be tested at full current or full voltage but not simultaneously.)

12.5.17 (Intentionally left blank)

12.5.18 During each heat run test, observe that the power supply current regulation meets all specifications.

12.5.19 Hydrostatic (pressure) testing shall be performed on each Power Supply prior to shipment to verify each system is leak free. Testing should be done at not less than 165 PSI for at least 30 minutes.

13.0 DOCUMENTATION

13.1 Preliminary Design Report (see section 11)

13.2 Monthly Progress Report

The vendor shall prepare and submit a Monthly Progress Report advising of the status of the program. It shall include a discussion of the program progress compared to the delivery schedule as well as touching on any other matters having a bearing on producing and delivering high quality power supplies to Jefferson Lab on time.

Each report shall cover the period ending with the last working day of the preceding month and is due at Jefferson Lab by the fifteenth of the next month. The report shall be sent to the Jefferson Lab Contract Officer and a copy sent to the Subcontracting Officer's Technical Representative.

13.3 Power Supply Documentation

Power supply documentation shall be furnished in both hard copy and electronic file format.

The Vendor shall furnish four (4 ea.) hard copies of the Installation Manual, Instruction and Troubleshooting Manual, and Final Drawing Set.

Word or PDF files shall be furnished on CD's or flash drives.

Schematics and other drawings shall be furnished in Auto CAD dwg format or in DXF format on CD's or flash drives.

Microprocessor software documentation shall include the source code and Program Memory listings on CD's or flash drives.

All drawing annotations, text, tables and other documentation shall be written in English.
The Installation, Operating And Trouble Shooting Manuals shall provide information about power supply installation, maintenance, typical adjustments, trouble shooting procedures, typical voltages and currents and detailed parts lists.

13.3.1 Installation Manual

The Installation Manual shall contain information pertinent to unpacking and initial mechanical installation and electrical hookup.

13.3.2 Operating Manual

The Operating Manual shall include at least the following:

a. A detailed theory of operation which fully describes circuit operation on a stage-by-stage basis, including plots showing control loop gain and phase versus frequency.

b. Recommended test procedures.

c. Normal wave forms to be expected.

d. Recommended routine maintenance procedures.

e. Parts list with vendor's type numbers.

f. Data sheets for power converters and heat sinks.

g. Data sheets for semiconductors.

h. Recommended maintenance procedures.

i. Typical adjustments.

13.3.3 Troubleshooting Manual

The Troubleshooting Manual shall contain detailed information about trouble shooting the power supply along with calibration and adjustment procedures that may be required. It is assumed that the vendor is expert in diagnosing and fixing these power supplies so as much information as possible should be included so that the supplies may be quickly fixed when problems occur. Procedures detailing replacement processes of major components shall be included.

13.3.4 Final Drawing Set

The Final Drawing Set shall include the following:

a. All schematics with component values

b. Interconnecting diagrams with all wire numbers, terminal block numbers, wire colors as used, plug types and pin numbers.

c. Required external connections, test points, outline dimensions.

d. Mechanical drawings of all assemblies and sub-assemblies within the power supply.

e. A detailed electrical parts list shall be included in the final drawing set. This parts list must show the part numbers of the vendor who originally produced the components

Each plug, terminal block, connector shall have a unique number. The Final Drawing Set shall be such that a technician can trace and follow each wire. Detailed drawings of mechanical subassemblies are not required. Sketches will not be accepted as final drawings. No compromise on the condition of the final drawings will be accepted. It is not acceptable to obscure the original parts markings and replace them with proprietary markings.

13.3.5 Recommended spare parts

Vendor shall furnish a list of recommended spare parts and pertaining manufacturer and part numbers.

ATTACHMENT 1

Monitoring & Control Commands
Via
RS485 Serial Link Interface

The following is a short description of the RS485 serial link interface and protocol to be used in the remote monitor and control mode. This interface will be one of up to (8) addressable nodes on an RS485 multiparty serial link or bus connected to an intelligent bus controller.

There are basically (3) types of message packets: *control commands*, *status commands*, and *status responses.* Control commands and status commands are issued from the controller to the Power Supply and tell the supply what to do. Status responses are issued from the Power Supply in response to the controller queries and report on operating conditions. Message packets are sent by transmitting a string of ASCII characters terminated with a LINE FEED (LF) and a CARRIAGE RETURN (CR).

The status response message must be a continuous, uninterrupted packet. The control command and status command message is not required to be continuous, allowing a remote “dumb terminal” to be used for monitoring and controlling the power supply “locally”.

The controller loops continuously and sequentially scans through the (8) power supply addresses in ascending order, 20 times per second. The controller first sends the command to *address* the power supply of interest. Upon receipt of this command, any power supply thus *unaddressed* (not having the command address) must immediately tri-state its transmitter. It should not respond to commands until again addressed. The addressed power supply, after a brief wait to allow all unaddressed units to go tri-state, enables its transmitter and responds to all subsequent valid commands until once again unaddressed. If an addressed power supply receives a bad command or communication error, it responds with a string consisting of an ASCII “?” and an ASCII “BELL” followed by the termination characters.

The response time by the power supply for all commands must be less than 50 milliseconds in order to prevent a “time-out” or “no response error”. The response time is defined as the time that elapses from the stop bit of the command termination character to the stop bit of the response termination character.

COMMAND SET:

(**Note: The power supply software shall be designed in a way that easily facilitates expansion of the command set.**)

Control Commands:

Description	Command
1. Set power supply address	ADR XXX
2. Turn main power OFF	F
3. Turn main power ON	N
4. Set output polarity	PO +, PO – (IF USED)
5. Set output current	WA XXXXX where X=0-9
6. Reset interlock fault	RS

Status Commands and Status Response:

Description	StatusCommand	Status Response
1. Read power supply address	ADR	A where A=0-7
2. Power supply control mode	CMD	"REM" or "LOC"
3. Power supply status	SXX..	coded status
4. Internal Interlock status	INTL1	coded status
5. External Interlock status	INTL2	coded status
6. Output setting	RA	XXX.XXX amps
7. Output polarity	PO	"+" or "-" (IF USED)
8. Redundant output current	ADO	XXX.XX amps
9. Output current	AD 8	XXX.XXX amps
10. Output voltage	AD 2	XXX.XX volts
11. Internal control voltages	AD 3-5	XXX.XX volts
12. Thermal control temperature	AD 6 +	XX degrees C
13. Transistor bank voltage	AD 7	XXX.X volts

Hardware Interface:

The vendor's serial link hardware interface shall adhere to the EIA RS485 standard for a multiparty bus. Configuration shall be a full-duplex, four wire. The data format shall be standard NRZ, 8 data bits, 1 stop bit, no parity. The baud rate and node address shall be selectable using jumpers, switches or readily accessible methods. The baud rate selections shall include 9600 and 19200 baud rates. The node address selections shall include addresses from 0 through 7.

The vendor's serial interface shall be galvanically isolated from earth ground and the rest of the power supply control circuitry. The Jefferson Lab installation requires the RS485 interface be presented as two daisy-chained standard DB9 subminiature receptacles. Twisted individually shielded pairs with separate drain wires and an overall outer shield shall be used with each of the shields carried through, but not terminated. The cable characteristics must adhere to the RS485 standard. The two connectors have identical pin-outs but must be connected together only at the power supply serial driver (receiver) interface in order to minimize the stub length. The pin-out for both connectors at the Power Supply terminal is as follows:

Pin Number	**Description**
1	RX.SHIELD
2	RX.LOW
3	OUTER SHIELD
4	TX.LOW
5	TX.SHIELD
6	RX.HIGH
7	COMMON (Isolated)
8	Not Used
9	TX.HIGH

ATTACHMENT 2

Water Cooling Hardware & Considerations.

The power supply shall be water cooled. Jefferson Lab has a closed-loop low conductivity water (LCW) system with the following specifications available to supply cooling water to these supplies:

Water Temperature:	35 + 2 degrees C.
Inlet Pressure:	140+ 10 PSIG.
Return Pressure:	75 + 5 PSIG.
Conductivity:	2 megohm/ cm.(minimum)
PH Range:	6.0 - 6.8
Maximum flow rate:	30 GPM +/- 10%
Outlet water temp:	Not to exceed 55 deg C.
Maximum Water Velocity:	10 feet per second

The following parameters shall be used in the water cooling system design:

For metals in contact with the LCW, only brass, copper, and stainless steel may be used. Aluminum, iron, and steel, whether plated or not, may not be used. Nickel-plated brass is not recommended.

Hoses shall be rated for a working pressure of 200 PSI minimum. They shall be manufactured of a material known to have a minimum life expectancy of 5 years under similar usage.

Hoses, fittings, and sensors shall be rated to withstand a minimum of two times the nominal inlet pressure to provide allowance for pressure transients, such as water hammers.

Hoses shall be secured using barbed-fittings augmented by stainless steel clamp rings.

Water cooling lines and fittings shall be located and where necessary guarded, so as to minimize the likelihood that a leaking line or fitting will cause damage to electrical or electronic components. Where possible, water connections shall be at the bottom of the enclosure.

An external flow monitor shall monitor water flow and drop out a contact in the case of underflow. The contact closure is an interlock to be monitored by the control system (See Appendix I). The power supply must shut off in the event of a water flow interlock failure and the status returned to the remote monitoring interface and front panel display.

Each parallel water cooling path shall have Klixon™-type over-temperature sensors mounted on the outlet end of the water circuit.

All cooling circuit plumbing must conform to ASME B31.x standards for pressure systems. (See following paragraphs)

JLAB STANDARD:

Maximum Allowable Working Pressure: 150 PSIG

Operating Pressure Differential: 70 PSID minimum

Jefferson Lab requires measures to be implemented for pressure safety. Because the power supplies include water-cooled systems that will be pressurized beyond 15 PSIG the following sections shall apply to the manufacture, testing, etc. of equipment supplied under this procurement.

Pressure Safety

Jefferson Lab has determined that national consensus codes are not applicable. However, vendors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME (B31.xx, vendor to decide applicable code) These measures must include the following:

(1) Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (i.e., professional engineer). The results of the analysis must be provided to the JLAB SOTR.

(2) Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, nondestructive tests, and acceptance test.

(3) Documentation, traceability, and accountability must be maintained for each unique pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance.

Vendors shall include in their proposals measures/procedures that demonstrate compliance with these requirements.

Documentation supporting these requirements shall be included with each power supply shipped.

APPENDIX I

External Interlocks & Interlock Indications

For safety of personnel and equipment, Jefferson Lab requires this power supply to be electrically interlocked to multiple pieces of external equipment. The following specifications detail the requirements for external interlocks.

1. There shall be provision for interlocking twelve external devices in such a manner that the supply output is positively de-energized when any of these external interlocks is *not satisfied* (open). The twelve external devices have been referenced in the specification as follows:

a. PSS (2) (Section 9.4)
b. Shunts (Section 6.1)
c. Shunts (Section 6.1)
d. Shunts (Section 6.1)
e. L.C.W. (Section 6.2)
f. Magnet Thermal switch (Section 6.2)
g. Water Flow monitor (Attachment 2)
h. (4) Spares

2. There shall be provision for the following interlocks internal to the power supply in addition to any interlocks the vendor deems necessary for safe operation of the power supply.

a. Ground Hook secure (Section 5.4)
b. Front Access Doors (2) (Section 9.5)
c. Rear Access Doors (2) (Section 9.5)
d. Emergency Stop (2) (Section 4.9.6)
e. Ground Fault (Section 5.1.2)
f. Phase Imbalance detectors (Section 9.8)
g. Heat sink over-temperature (Section 8.18)

3. Each external interlock will consist of an isolated electrical contact which will be *closed* when the interlock *is satisfied* and open when it is unsafe for the power supply output to be energized. The ratings of these contacts will be 24VAC/DC @ 100 mA maximum. They are not suitable for “dry” circuits (i.e. < 5VDC or < 10mA). All voltages used in sensing the state of the external interlock switches shall be derived from the power supply control power.

4. For external PSS interlocks, internal Access door interlocks and the Emergency stop, there shall be two independent interlock inputs, referred to as the *primary* and the *secondary* interlock loops, respectively. The summation of all the primary external interlocks shall be connected to the primary loop, which shall drop out the main output contactor, and the summation of all the secondary external interlocks shall be connected to the secondary loop which shall drop out the main contactor and inhibit operation of the power conversion circuitry, such as the power switcher firing circuits.

5. External interlocks and status indicators for PSS must be grouped to a separate connector available from the top rear of the power supply. Interlocks for shunts must be on a connector separate from other interlocks. Interlocks for L.C.W., flow monitor and Magnet thermal switch must be on a single connector separate from other interlocks. Spare interlocks must be on a single connector separate from other external interlocks.

6. The status of each of the primary and secondary external interlocks shall be displayed by a green front panel LED indicator. The LED shall be *on* when the interlock is satisfied. Each interlock status shall correctly display, regardless of the state of any other interlock (the interlocks shall not be connected in a chain such that operation of one disables others in the loop).

7. For each of the above LEDs, a signal of either 5VDC or 24VDC referenced to a common ground shall be presented at a terminal strip for external monitoring. The signal shall be present when the LED is *on*.

8. It shall be possible to interrogate the status (open or closed) of each external interlock input, via the RS-485 remote control link. See Section 4.8 and 4.9 and Attachment 1.

9. For purposes of labeling status indicators, Jefferson Lab will furnish the Vendor a list of names to be assigned the 12 external interlock inputs within 30 days after contract award.

10. For the primary and secondary interlock loops, individually, there shall be two sets of isolated interlock status contacts which will be monitored by User-defined equipment. One set of these contacts shall be closed when the summation of all interlocks comprising that loop are *satisfied* (N.O.) and one set shall be closed when the interlock loop is *not satisfied* or *when control power is off* (N.C.) The ratings of these contacts shall be 24VAC/DC @ 100 mA minimum.

APPENDIX II

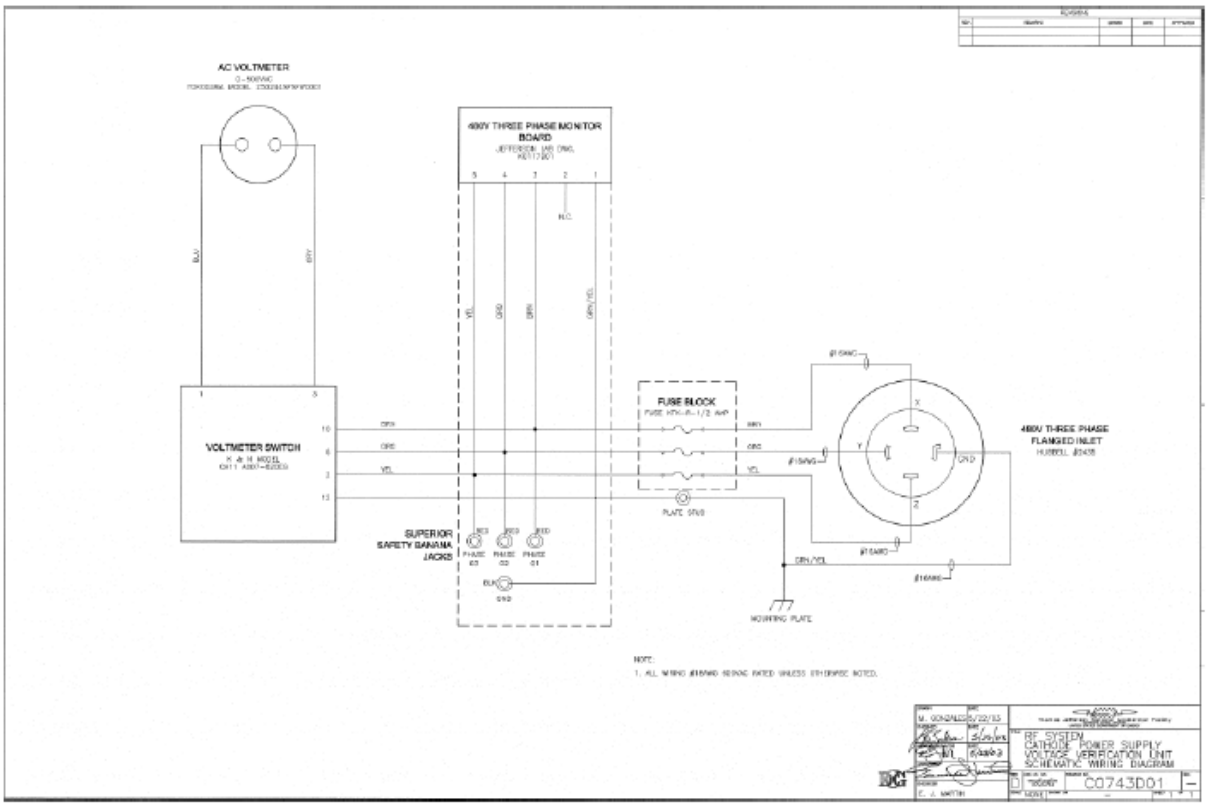
Power Supply DC Output Requirements

Power Supply	Operating Current (DC Amps)	Operating Voltage (DC Volts)	Operating Output Power (kW)	Rated Output Current (Amps)	Rated Output Voltage (Volts)	Rated Output Power (kW)	Tap Setting for Transformer
Pair Spectrometer	1100	36.3	40	**1375**	**40**	**55**	**80%, 60%, 40%**

Load Characteristics	
Tolerance: 3% on Resistance	
Power Supply	**Resistance (mohms)**
Pair Spectrometer	0.03

APPENDIX III

Typical JLAB VVU Schematic



APPENDIX IV

Power Supply	Water For Cooling (gpm)	Footprint W x D (feet)
Pair Spectrometer	**20**	4 x 6