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**PPD / EED / Infrastructure and Support Group**

Technical Note: IG\_ 20150003

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**Linear Coherent Light Source – II**

**Vessel Demagnetization**

**Programmable Current Source /**

**Current Distribution**

**Overview:**

Anthony C. Crawford (Fermilab Technical Division) has successfully demonstrated a method of demagnetizing large cylindrical steel vacuum vessels destined to be used for the LCLS-II project at SLAC. Simply stated, a vessel is to be subjected to magnetic fields of reversing direction and diminishing strength. Coils around the vessel carrying current from a programmable current source will provide the magnetic field. It is envisioned that the vessels will be subjected to this demagnetization process as they are received from the vessel vendor, after the associated cryogenic piping and RF Cryo-modules have been installed and perhaps in situ at SLAC.

It is expected that a current waveform (truncated triangular) with a maximum amplitude of 65A will be run through the coils in both directions. The estimated period of this two-direction cycle is 25 to 30 seconds. The amplitude of the current in subsequent cycles will be reduced by some fraction until some terminal current value is reached. The entire process should take about 30 minutes.

Members of the PPD / Electrical Engineering Department have been asked to develop a process of implementing this method to demagnetize a number of vessels. We see this effort broken into the following tasks: Specification of a programmable current source and associated current distribution equipment. Specification of the current carrying conductor(s) that comprise the coils. Working with Technical Division staff to physically realize the coils. Specification of the method of connecting the coils to each other or to current distribution equipment as appropriate. Realizing the system in a safe manor capable of passing installation inspections at SLAC, Fermilab and Jefferson Laboratory (a parallel vessel assembly site).

This note presents a proposal for a realizing and controlling the current to be supplied to the demagnetization coils.

**Background:**

Proof-in-principle demonstrations of the demagnetization of large cylindrical vacuum vessel by Anthony C. Crawford have utilized a four-quadrant power supply supplied by the Accelerator Division of Fermilab. As a bi-polar supply, this device is able to source and sink current – a desirable attribute for a demagnetization project. Limited availability (the supply used is one of two AD spares) and worries about maintenance make this power supply a poor choice when considering at three possible installations (two remote).

It is anticipated that a LabView program (or equivalent) will generate a current programming voltage that will be delivered to the chosen power supply. The amplitude of the current will be proportional to the programming voltage.

**Power Supply Requirements:**

The maximum estimated resistance of the three coils (two Trim Coils and one series of Helmholtz Coils) in series is 1.1Ω. The maximum desired demagnetization current is believed to be 65A. The voltage required to drive this current is thus about 72V. Power associated with this voltage and current is 4.7kW. Investigatory work done by Anthony C. Crawford indicates that the current offset for the supply should be less than 200mA.

**Power Supply**:

Searches for commercial bi-polar power supplies capable of delivering nearly 5kW were not fruitful. We’ve consulted with Steve Hays (Accelerator Division power supply expert) who explained that while they would be willing to make more of the four-quadrant supplies (they’d just completed the second spare), the labor cost would be extremely high and maintenance issues would remain. While a low-level search will continue for commercial bi-polar supplies, we’ve concentrated our efforts on providing the desired current waveform and accuracy using commercial uni-polar (single quadrant) switch -mode supplies. Steve Hays recommended a particular manufacturer that they’ve been purchasing power supplies from in lieu of designing and building them themselves.

Magna Power has three power supply options in the 6kW to 10kW range that seem to meet our requirements. The ripple for each at 80V is listed as 60mVrms, which would translate to about 66mA. The current programming accuracy is listed as ± 0.0075% of full scale current. All have programming inputs for controlling the output current. Additionally, all have other optional programming interfaces available. Output (voltage and current) monitoring is available as well.

Of particular interest are the input power options. We’ve discussed the possibility of providing a crash button and perhaps other safety interlocks into the current distribution system. The Magna Power User Manual indicates that a “STOP” input is available. Asserting this input disables the power supply output. We will also examine the feasibility of dropping the AC power to the supply as a response to a loss of interlock signal. The only two realistic input power options that Magna Power lists for supplies we are considering are 208Vac 3Φ and 440Vac 3Φ. The circuitry required to provide control the current distribution system, power the interlock signal and to monitor system conditions inevitably requires a source of 120Vac. For safety reasons, we plan to be able to create a single-power cord solution for our current source / distribution system. One source of power to a system simplifies the concept of Lock Out Tag Out should it be necessary. Without the purchase of a transformer, the realization of 120Vac single-phase from 440V power is not possible, a task easily accomplished from 208V. Thus our recommendation is for a 208Vac 3Φ input power option for the supply. The choice of power supply will dictate the current (per phase) that the power supply might draw as well as the nature and rating of the connectors, cables and circuit breakers for ac power at each possible installation site.

In this light, the 6kW supply seems the most reasonable choice. Expected current draw (per phase) for this supply is listed at 22A. The choice of this supply would allow the use of standard NEMA L21-30 plugs and receptacles and 30A circuit breakers. The cost of this supply is about $4,800.

**Current Distribution System:**

The primary method of demagnetizing a vacuum vessel is to run current through the coils in one direction for half of the cycle then in the other direction for the remainder of the cycle. A uni-polar power supply is incapable of this sort of operation so ancillary equipment is required. We propose realizing a reversing switch with a pair of contactors and a pair of solid state relays. The connection diagram included at the end of this document depicts this arrangement. Details for the Power Distribution Block are not included at this time as we work to understand installation requirements for three possible sites. When fully understood, power distribution details (including interlock options, fuse ratings and wire gauge information) will be provided in a separate drawing.

It is assumed that the program that generates the current reference voltage will also generate the forward and reverse current enable signals. It’s also possible that an interface circuit could be designed and placed in series with the output(s) of the program to assist in this function.

With the Forward Current Enable input asserted the upper contactor pulls in, providing access to the coil. The voltage to the Current Reference input is manipulated as required for the current cycle, starting and finishing at 0A. It’s our understanding that when programmed to 0A, the output section of the Magna Power supply is disabled and no current is sourced. We will investigate the use of a current monitor to ensure that contactors are not changed with current present in the coil. De-asserting the Forward Current Enable and asserting the Reverse Current Enable provides access to the coil in the opposite polarity. The Current Reference voltage is run through the same waveform. The cycle repeats until the vessel is deemed demagnetized.

A fuse (currently expected to be 75A) placed in series with the output of the supply will be used to set the gauge of wire used in the current distribution system. In the unexpected situation where both contactors are pulled in, the power supply is fuse and short-circuit protected and an appropriately sized reverse-biased shunt diode offer system protection.

We’ve located appropriately rated contactors and are awaiting quotes. Should an appropriately rated commercial reversing contactor / switch be found, the current distribution system may be modified accordingly.

It’s envisioned that the supply, the power and current distribution systems and the control / monitoring / interlock hardware will all be installed in a small, moveable 19 inch equipment rack. The design of all systems will be reviewed to ensure compliance with all applicable SLAC, Jefferson and Fermilab safety standards.

Appendix:

M. Cherry, et al. “*LCLS\_II Vacuum Vessel Demagnetization Connection Diagram*”, Drawing 176937, 24-July-2015.