Wang NMR, Inc.

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MICE TRACKER MAGNET COMMENTS, CONCERNS & QUESTIONS

PS&ControlNotesA.doc
November 10, 2009

The following are items of concern that arose during the design & testing of the Tracker magnet, power supplies, programmer, protection system and magnet instrumentation.

1.0. Personnel Protection System (PPS)

1.1. PPS to disable power supply output(s) only.
AC mains power to power supplies remains uninterrupted.

Both the XANTREX and POWER-TEN 300 ampere power supplies have isolated inputs which can be connected for the PPS. Figure 1 shows a schematic for implementing this feature. The power supply output will be inhibited until the external contact closure is present.

The two Lake Shore 60 ampere power supplies have a logic level input which will inhibit the output. However the logic level sense is inverted (Logic High = Inhibit). In addition, the logic inputs on the Lake Shore supplies are not isolated from the frame or mains ground. This makes it difficult to interface these inputs directly with the PPS control and is likely to present grounding problems. This problem could be solved by the addition of a low power relay (12 V). A small power supply (12 VDC @ 1 A) is being installed in the cabinet to provide power for controlling the large contactors. This power supply could also power the PPS relay for the Lake Shore supplies.

1.2. Implementation of the PPS would be more difficult if the requirement is to remove the primary AC mains power from the power supplies. This would require the addition of a 100 ampere, 3 phase mains power contactor. This cannot not be accommodated into the present cabinet because of space limitations.

1.3. Power ON sequencing caution.
NOTE: There is a danger of a high voltage or current surge if the AMI 420 programmers are not turned on and configured properly before the 300 ampere power supplies are enabled! Proper power-on & enabling sequencing must be observed! (See item 5.0).

It is highly recommended that a PLC (Programmable Logic Controller) be installed in the power supply cabinet to perform the Power-On sequencing. The PLC would also provide the proper signal levels to all of the power supplies for the PPS and other interlock functions. (See ITEM 8.0)

The Power-On sequencing will be performed manually during the magnet factory testing.

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2.0. Power supply "GROUND" reference.

2.1. Three-Hundred Ampere Power Supplies.

The DC output of the three 300 A power supply and their associated magnet coils were not referenced to earth ground. A DC path to ground is required to avoid the build up unsafe voltages due to leakage from other circuits, electrostatic effects or from an equipment fault.. The output of each power supply is being grounded through a 10 ohm, 50 W resistor which is connected from the power supply negative terminal to the frame (earth) ground. The purpose of the resistor is to limit the fault current to a safe value in the event of a direct ground occurring in the charging circuit. See Figure 2.
The voltage across these resistors should be monitored during operation to give a warning of excessive leakage to ground. The leakage current can be monitored by external instrumentation at TB5 in the power supply cabinet. A suggested limit is 0.100V maximum (10 mA) during charging of the magnet and 0.010V (1.0 mA) during steady state operation.

2.2. Lake Shore 60 Ampere Power Supplies.

These power supplies are used for trimming the current in coils E1 & E2. Since they are connected directly across each end coil they should be floating with no connection to ground. The Lake Shore user manual states that there is a 100 ohm resistor connected internally from the power mains ground (frame) to the negative power supply output. An ohm meter measurement indicates a resistance of about 7,000 ohms when the power supply is off. When the supply is operating, a DC potential with a 100 ohm series resistance is measured relative to frame ground. This varies from +1.5 V to 6.0 V, depending upon the power supply output voltage. This ground current can be as high as 60 mA and will flow through the magnet coils to ground. This will cause interactions while making current adjustments and an error in accurate current measurement. Since the ground currents are not constant and the ground impedance is subject to great variability, the overall coil current regulation may be compromised.
Questions:

- Will the 60 mA current affect the operation of the Tracker magnet?
- Will the interaction during end coil currents adjustment a serious problem?
- Can this resistor be increased to 1.0 K?
  Information from Lake Shore says that the 100 ohm resistor can be removed but this will void any guarantee.

3.0. AC Mains Power Distribution.

The wiring and terminal block (TB1) for the AC mains power distribution has been set up to accommodate factory testing only. The mains wiring has not been specified and must be designed to satisfy the installation requirements. Figure 3 shows a recommended wiring where the power supply cabinet is powered from four circuits, 208V, 3-phase, at 30 A each.

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4.0. Quench Detection

The quench detection circuitry of the AMI 420 programmer is triggered whenever the actual current being sensed differs from the programmed current by "some prescribed value". The magnitude and timing of this inequality is not defined in the AMI User's manual nor could it be specified by their engineering service. The quench sensitivity is not user programmable on this model. The quench detection can only be enabled or disabled by the user.
More detailed information will be required before the AMI 420 quench detection function can be used with confidence. If the AMI quench detection circuitry is not suitable, an alternative means of quench detection must be implemented.
Note: If it proves necessary, the AMI quench detection circuitry will be disabled during magnet factory testing and training. These tests will be closely monitored and the power supply & discharge control will be performed manually upon magnet quench.

5.0. AMI Power Supply Programmer.

5.1. Operational Concerns .

The AMI 420 regulates the power supply current by controlling the power supply output voltage as required to achieve and maintain the programmed current. The programmer output (Vs) directly adjusts the power supply voltage. (Vs) varies in response to the difference between the current sensed and the required programmed current. If the power supply is disabled while the programmer is enabled, the programmer commences to ramp (Vs) towards the maximum output limit in an attempt to attain the programmed current. The programmed current cannot be attained since the power supply is disabled. If the power supply is now enabled, it's output will go to the high voltage as determined by (Vs). As soon as the controller senses that the current is above the programmed value, (Vs) will begin to ramp towards zero. However, depending upon the stability setting of the programmer, this may require a long time.

5.2. Feed-back Stability Setting.

To assure that the current regulating feed-back loop is stable, a "Stability" constant must be loaded into the programmer. The optimum value depends upon the magnet inductance. Experience during magnet testing has shown that a stability of 100% works. The response of the programmer is very slow with this setting. A delay of up to a minute has been noted before when starting. This is not expected to be a problem.

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5.0 Single Quadrant Power Supply.

The 300 ampere power supplies that were provided, operate in a "Single Quadrant" only. That is they can only source current at a positive voltage. In order to reduce the magnet current, it is necessary to reverse the voltage at the magnet coil to remove the stored energy. The 'I*R' voltage drop in the charging cable is the only means of reducing the magnet current when a single quadrant power supply is used. The time constant for discharging the magnet through the charging cables would be on the order of two hours. The large difference between the charging & discharging time constants would make it very difficult to stabilize the power supply and current feed back system. (See Section 6.)

NOTE: A rapid "emergency dump" is possible by opening the contactors in the charging circuit. This disconnects the power supply to allow the energy that is stored in the charged magnet to be dissipated in the parallel diode assembly which is water cooled. This will be a complete discharge can cannot be used for "trimming" the operating current.

6.0. Power Supply Programmer, AMI 420.

The AMI Model 420 Power Supply Programmer regulates the power supply current by controlling the power supply output voltage as required to achieve and maintain the programmed current. The programmer output (Vs) adjusts the power supply voltage in response to the difference between the current sensed and the required programmed current. If the power supply is disabled while the programmer is enabled, the programmer commences to ramp (Vs) towards the maximum output limit in an attempt to attain the programmed current. Since the power supply is disabled, the programmed current cannot be attained. If the power supply is now enabled, it's output will go to the high voltage as determined by (Vs). As soon as the controller senses that the current is above the programmed value, (Vs) will begin to ramp towards zero and eventually regain control. However, with the "single quadrant" power supply the time for recovery back into a regulating state will be extremely long. A similar problem will occur whenever the programmed current is reduced to adjust to a lower value.

This is being corrected by connecting a string of diodes in series with the output of each 300 ampere power supply. See drawing PSP19-60. These provide a voltage drop of approximately 3 volts for the Match 1 & Match 2 coils and 8 volts for the Center coils. This will permit the voltage at the magnet coil to be reversed to provide bipolar operation. These series diode assemblies are identical to the parallel assemblies used for fast discharge. See drawings PSP19-63 & PSP19-64.

The main disadvantage of this power supply configuration is the power dissipation which may be as high 3500 watts. The water cooling requirements are shown in drawing PSP19-62. The power dissipation with a true Two-Quadrant power supply would be significantly less.

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7.0. Volt Tap Isolation & Current Limiter.

The instrumentation that will be connected to the magnet voltage taps must be "floating" from ground and not present a significant load which could affect the magnet current. The voltage tap circuits must also be protected from large fault currents since these might damage the small size, low heat leakage wiring within the magnet. Current limiting resistors should be connected in series with each voltage tap, located physically as close to the magnet service tower as practical. A connector box which places a 1.0 K resistor in series with each voltage tap lead is recommended. See figure 5. Voltage limiting (clamping) should not be required since the internal magnet protection diodes and the external parallel diode assemblies in the power supply cabinet will limit voltages due to a fast discharge or quench. It is recommended that isolation amplifiers be installed for all voltage taps.

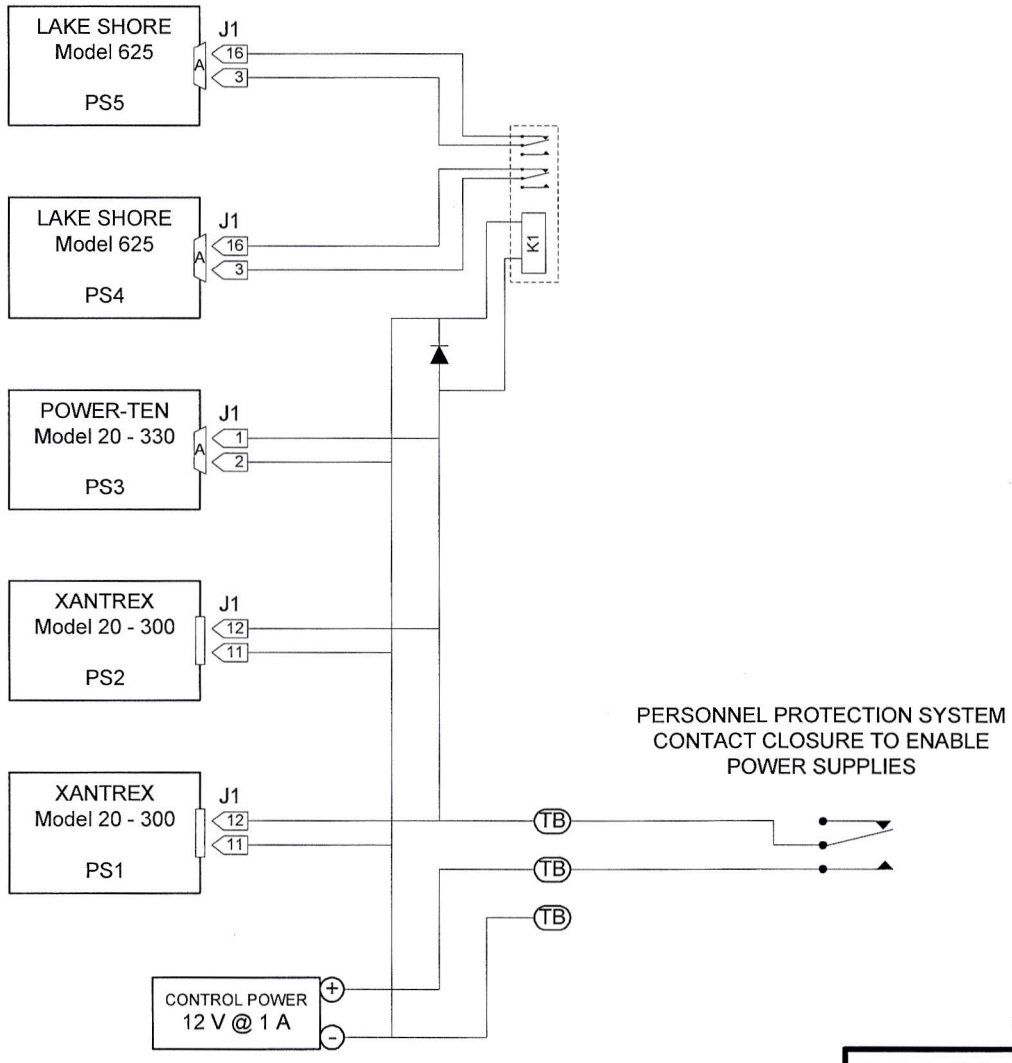
8.0. PLC (Programmable Logic Controller)

It is recommended that a PLC be installed within or close to the power supply cabinet to control the various power supply functions:

- Control PPS functions.
- Sequence the power supplies and programmers during power on.
- Monitor the quench output from each programmer & initiate fast discharge.
- Store "first coil to quench" information required for fault analysis reporting.
- Operate the contactors for fast discharge.
- Other interlock as may be required for personnel and/or equipment safety.
- Power supply and control status reporting functions.

9.0. Instrumentation Cables to Magnet

It has been necessary to modify the cables which were supplied. The cables from magnet J1 & J4 had PT100 & CERNOX type temperature sensors mixed up between the two input connectors to the Lake Shore Model 218. Each input connector can only accommodate four sensors of the same type. For test purposes, a short adapter cable was fabricated to reroute the sensors to the proper input. A better solution would be to fabricate an adapter box to reroute these connections. Rewiring of the cables is not practical since wires would have to cross between the two cables. By using an adapter, the two cables would remain physically independent of each other. The adapter box would also contain connector(s) for three auxiliary PT100 temperature sensors.
Pin "19 V" on magnet J1 is "-I" common to both liquid helium probes. This pin was actually connected to the shield ground at J1 and the wires from pin "19V" were not connected at the connectors at the two LHe meters. This wiring was corrected as necessary. The shields should not be connected at the magnet end of the cable. This is necessary to eliminate the possibility of ground currents. It is presumed that, when installed, the magnet frame will be connected to earth ground through mounting and plumbing etc.



NOTES:

1.

2.

3.

4.

10:47 | 09/03/09 | PPS_INTERLOCK.VSD

PPS INTERLOCK
TRACKER MAGNET
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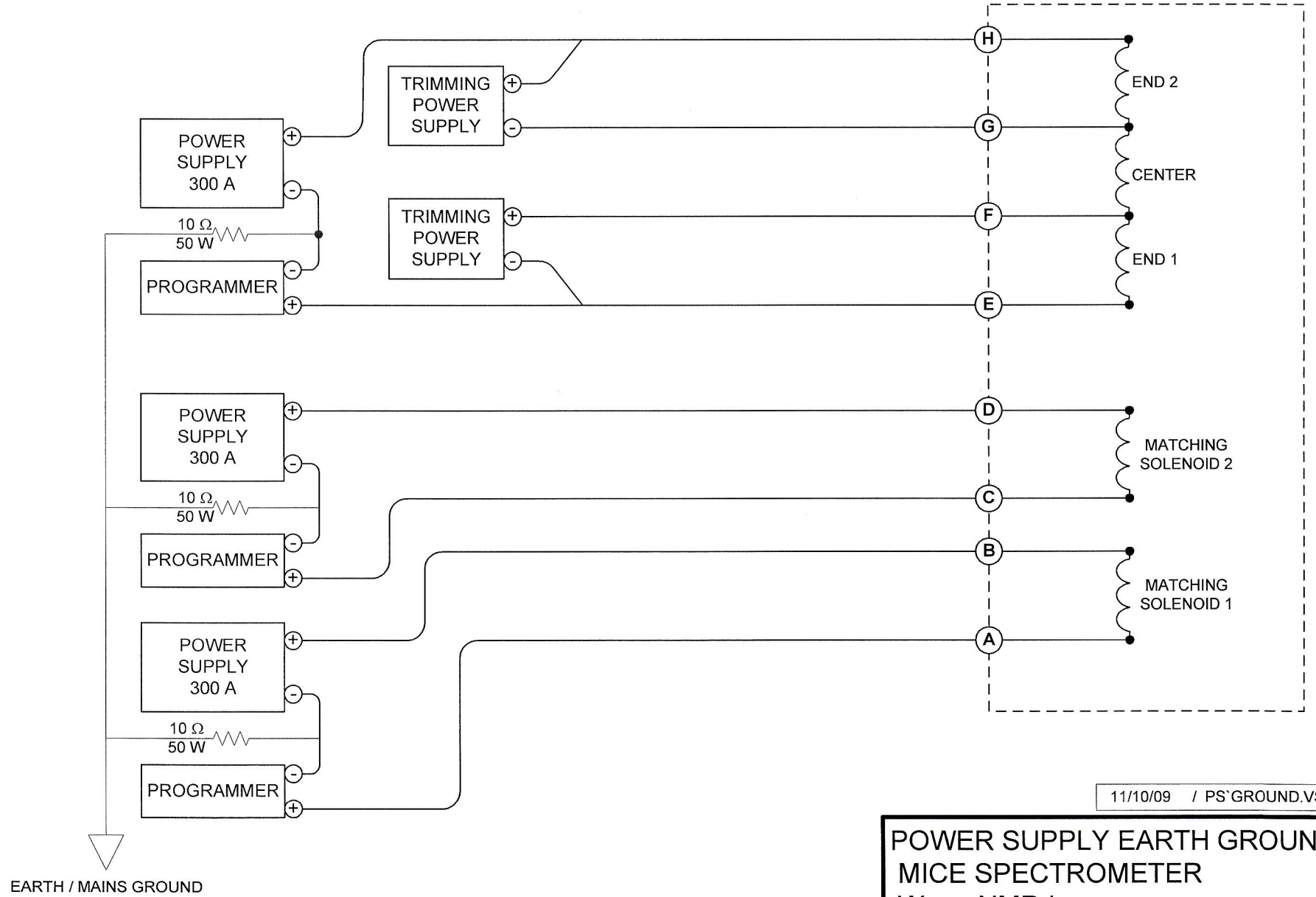
FIGURE 1



11/10/09 / PS`GROUND.VSD

POWER SUPPLY EARTH GROUND
MICE SPECTROMETER
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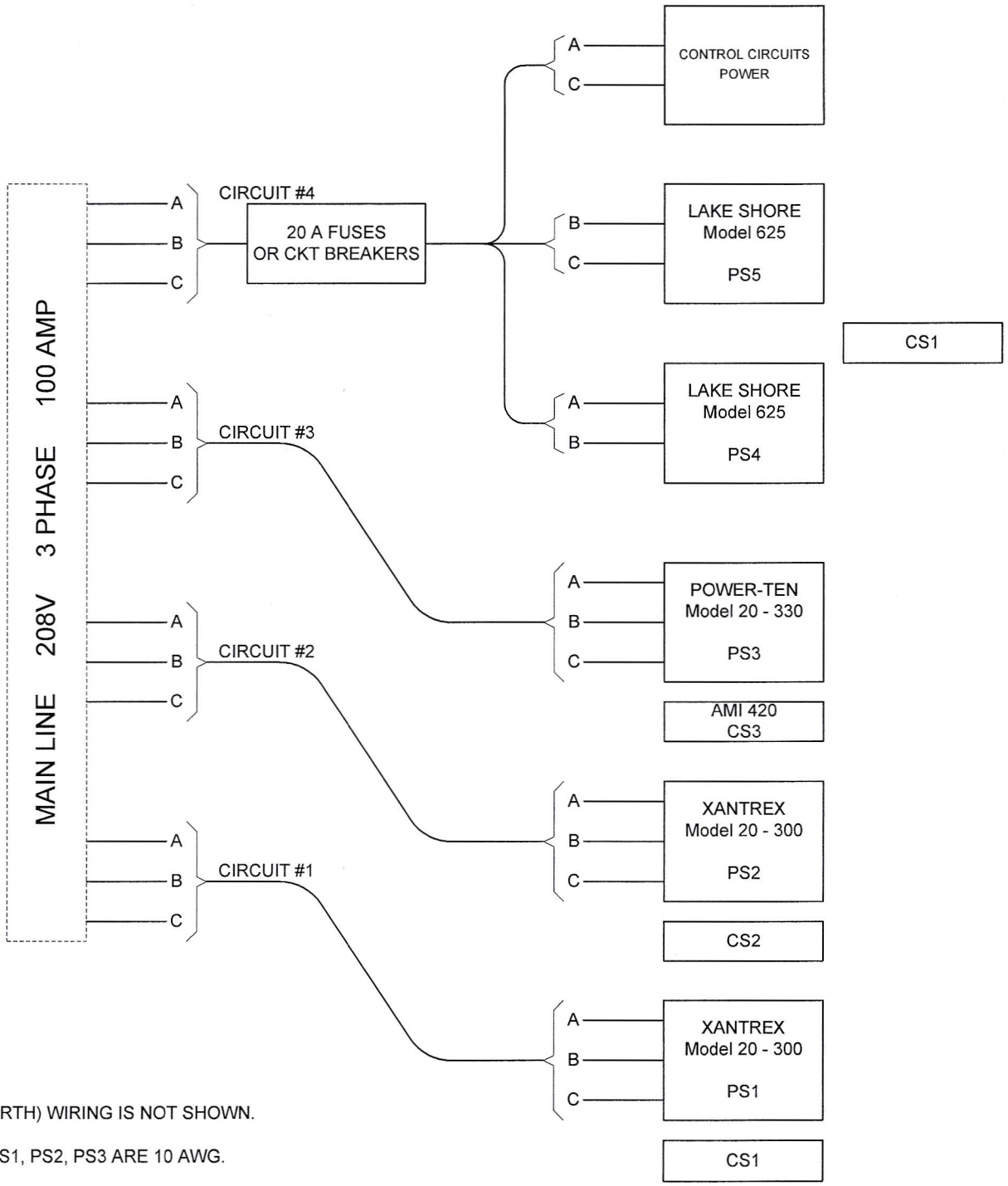
Figure 2



NOTES:

1. GROUND (EARTH) WIRING IS NOT SHOWN.

2. WIRING TO PS1, PS2, PS3 ARE 10 AWG.

3.

4.

17:46 | 07/09/09 | MAINSPOWER#1.VSD

MAINS POWER WIRING
TRACKER MAGNET
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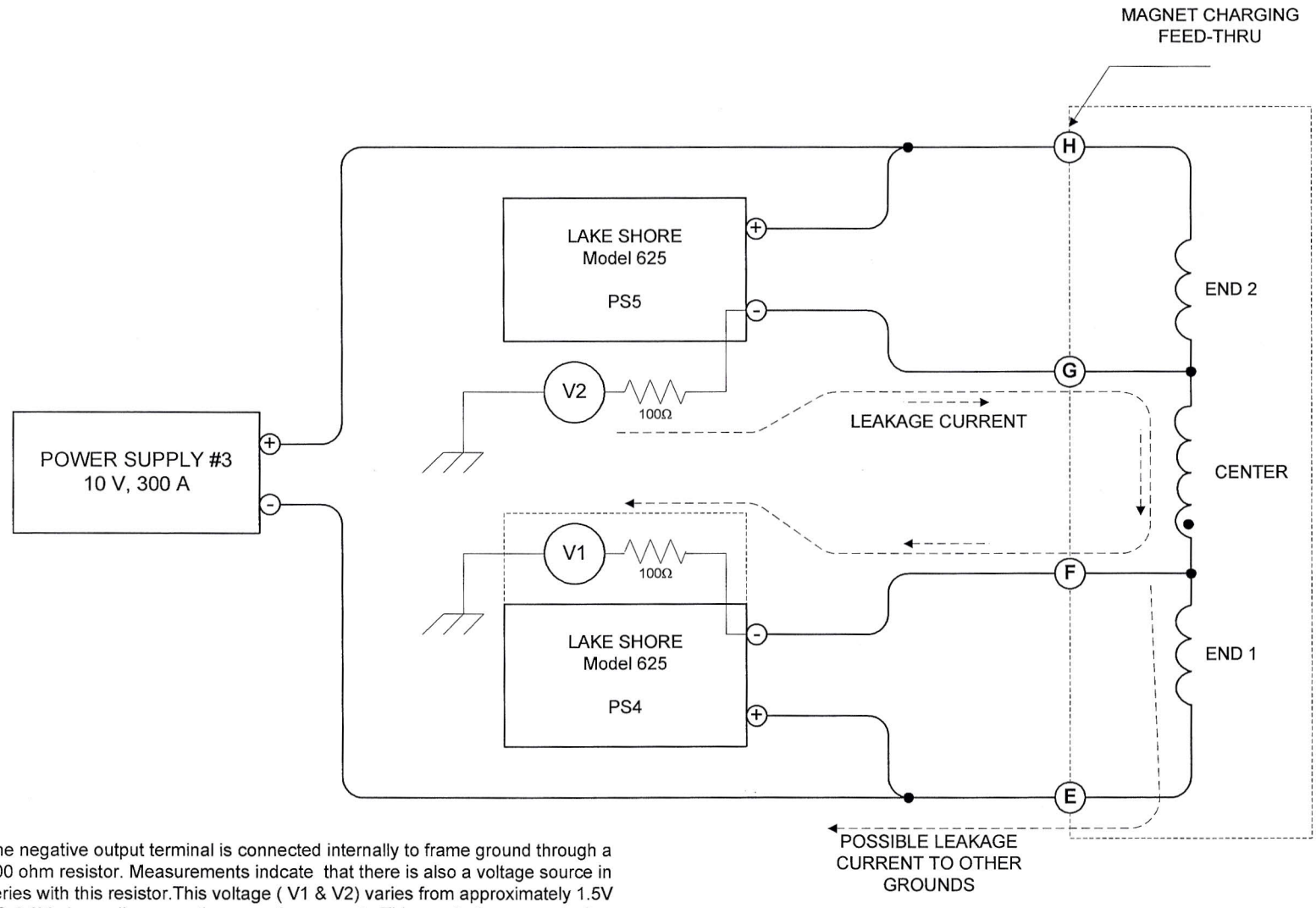
FIGURE 3



The negative output terminal is connected internally to frame ground through a 100 ohm resistor. Measurements indcate that there is also a voltage source in series with this resistor.This voltage (V1 & V2) varies from approximately 1.5V TO 6.0V, depending upon the operating current. This results in a current of up to 0.060 amperes which will flow through the center coil to the other power supply. The result is that adjusting the trimming power supplies will also alter the current in the center coil by this amount.

The trimming power supplies MUST be isolated from ground.

15:08 | 07/09/09 | LAKESHOREGND.VSD

GROUNDING, TRIM POWER SUPPLIES
TRACKER MAGNET
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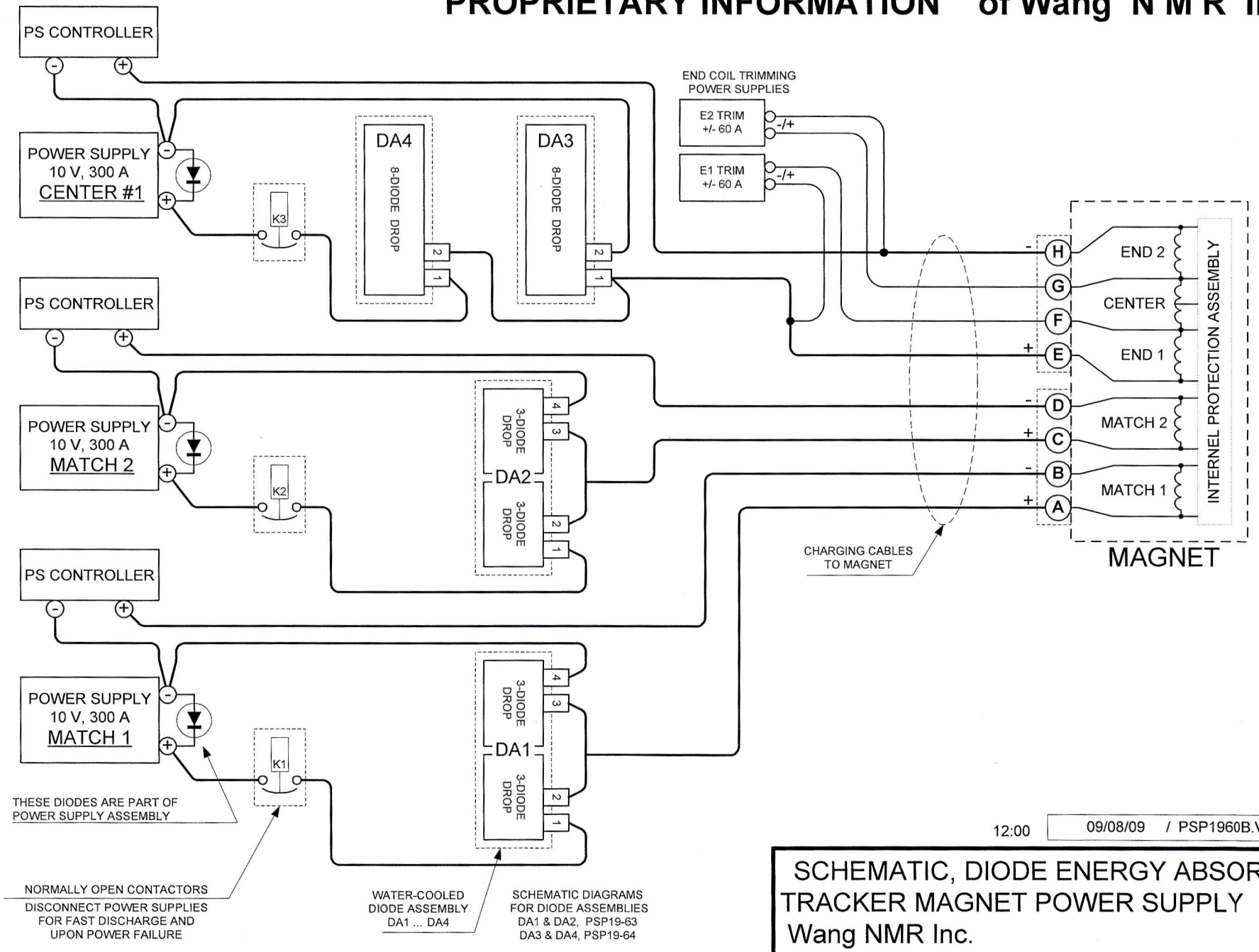

12:00 09/08/09 / PSP1960B.VSD

SCHEMATIC, DIODE ENERGY ABSORBER TRACKER MAGNET POWER SUPPLY

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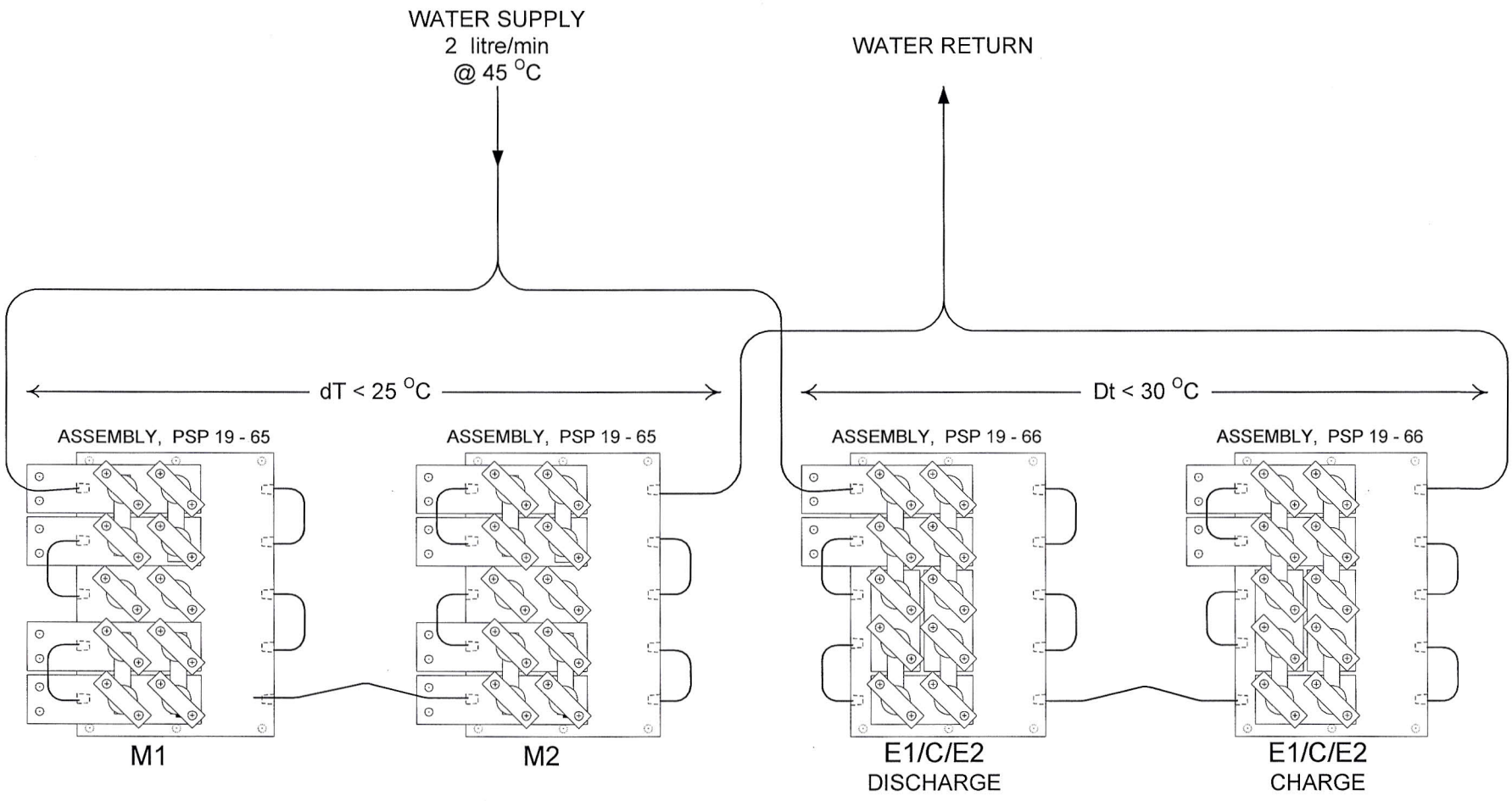
PSP 19 - 60 B



POWER
CHARGE =750 W
DISCHARGE = 750 W

POWER
CHARGE =750 W
DISCHARGE = 750 W

POWER
CHARGE = 0 W
DISCHARGE = 2000 W

POWER
CHARGE = 2000 W
DISCHARGE = 0 W

08/27/09 PSP1962A.VSD

PROPRIETARY INFORMATION
of Wang N M R INC

COOLING WATER REQUIREMENTS
TRACKER POWER SUPPLY
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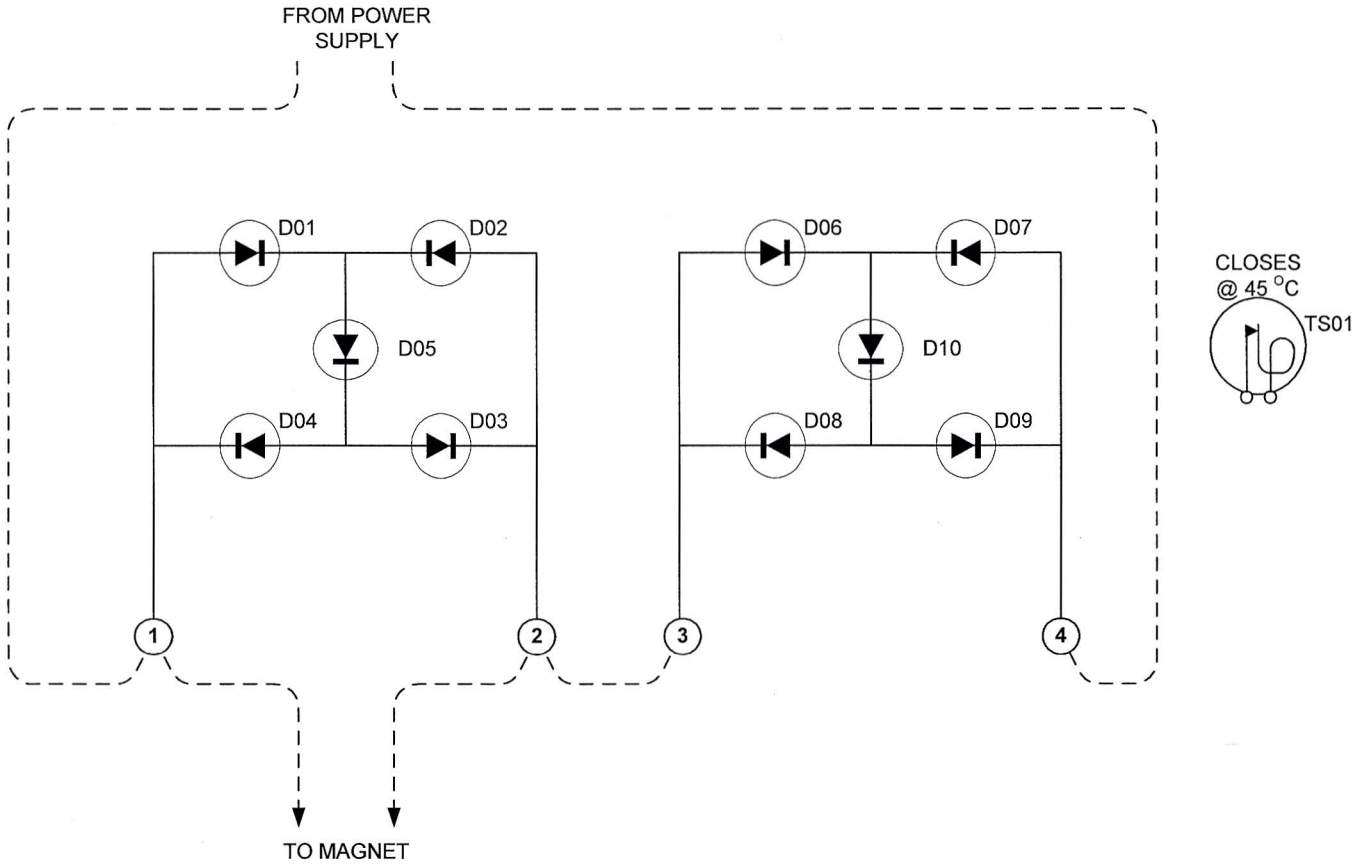
PSP 19 – 62 A

8/27/2009 2:36 PM



DIODE ASSEMBLIES DA1 & DA2
ASSEMBLY # PSP 19 - 65

14:38 08/27/09 PSP1963A.VSD

SCHEMATIC, DUAL 3-DIODE DROP ASSEMBLY
TRACKER MAGNET POWER SUPPLY
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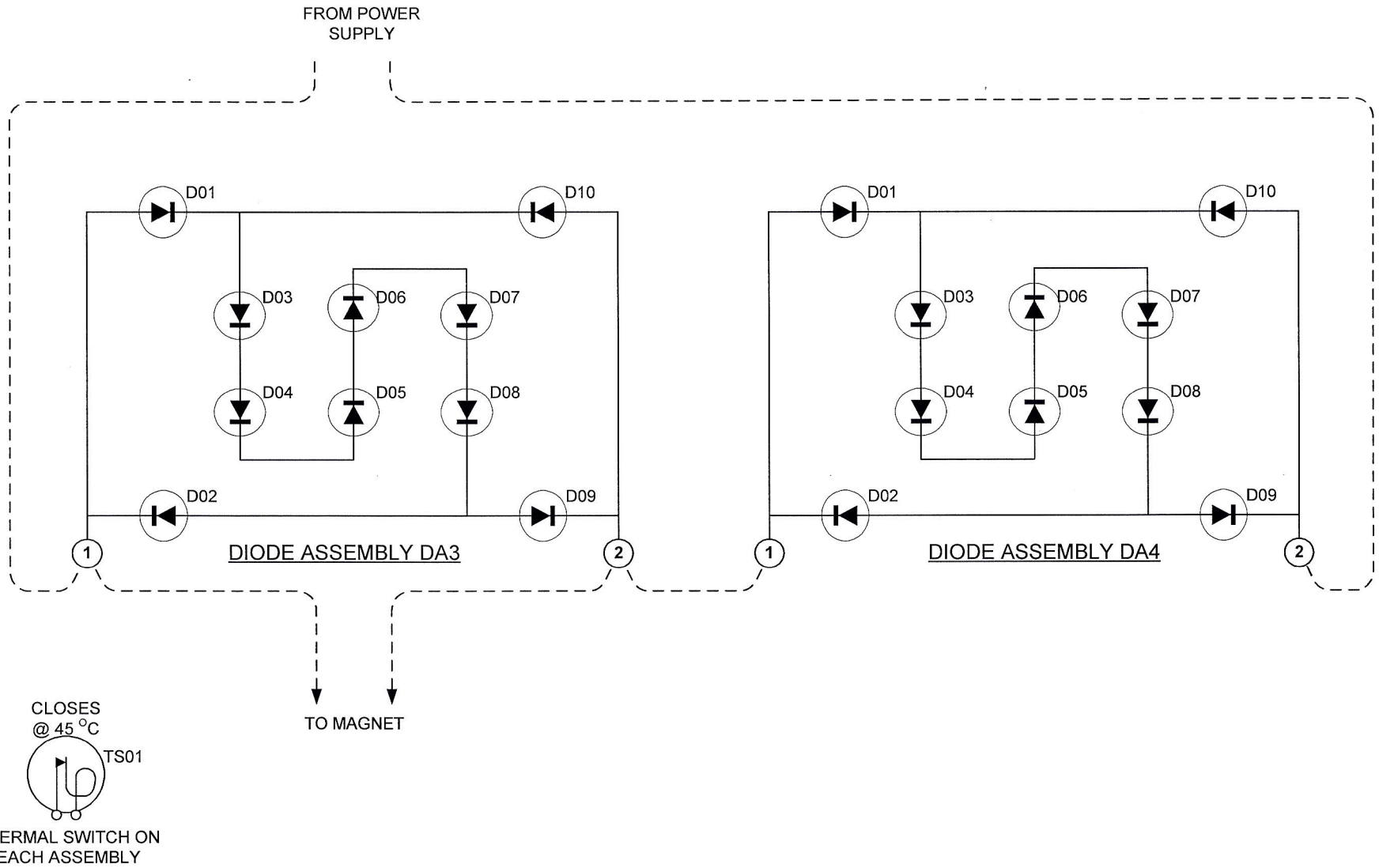
PSP 19 – 63 A



DIODE ASSEMBLIES DA3 & DA4
ASSEMBLY # PSP 19 - 66

08/27/09 PSP1964A.VSD

SCHEMATIC, 8-DIODE DROP ASSEMBLY
TRACKER MAGNET POWER SUPPLY
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PSP 19 – 64 A

1.50