T962 Electronics Documentation for ORC Review

Introduction

T962 – ArgoNeuT – is a liquid argon TPC detector – LArTPC - located in the Minos underground hall directly in front of the MINOS detector. This detector had a previous commissioning run at PAB Aug-Oct 2008. The systems described here were operated in their current state at PAB.

The T962 readout electronics consists of two main portions – a green box located on the top of the T962 cryostat which holds pre-amplifier boards, and a VME crate located in a relay rack nearby which holds the digitization and DAQ electronics. This relay rack, called the T962 DAQ rack, is located on the upper level of the MINOS platform, at the top of the stairs. The arrangement underground is shown in Figure 1 on page 8. The LVPS which serve the pre-amplifiers are located in the relay rack, with wiring running between the rack and the green box. Readout cables also connect the green box and the VME-based digitization boards. This document describes these parts in two main sections titled **Pre-amplifier System** and **VME Readout and DAQ System**. Attention is given to the DC power supply wiring and fusing. The electronics boards are also described, with attention given to their power and ground paths and references for further details.

The designer and contact for the entire system is :

Dan Edmunds
Fermi Phone: x2832
MSU Phone: 517-884-5521
Email: edmunds@pa.msu.edu

Pre-amplifier System

This section describes the preamplifier system and its power supplies that are the front-end of the T962 LArTPC readout. These preamplifiers are located in the large green box on top of the T962 cryostat. The power supplies for these preamplifiers are located in the T962 DAQ relay rack.

The preamplifier cards in the green box are called the PFC-16 cards (Preamp Filter Card 16 channels). In the Preamplifier Box the PFC-16 cards are held in two card files - the upper and the lower preamp card files. Each of these card files has its own Preamp Power Supply chassis and its own Fuse Panel. An overall block diagram of the T962 preamp power system is shown in Figure 2, on page 9. Photos of the green box, before cards and cabling were installed, and the full installation as it was commissioned at PAB, are shown in Figure 3 on page 10.

The components of this system (given in the order of the power flow) are: Preamp Power Supplies, Preamp Power Cables, Preamp Fuse Panels, PFC-16 cards. Each of these components is described below.

Preamp Power Supplies

There are two identical Preamp Power Supplies, both located in the T962 DAQ rack on the upper MINOS platform. Each Preamp Power Supply chassis contains 4 separate commercial linear open frame power supplies. A schematic drawing of the Preamp Power Supply is shown in Figure 4 on page 11.

Each Preamp Power Supply chassis supplies power to 15 PFC-16 cards. The 4 supplies in each Preamp Power Supply chassis provide a total of about 125 Watts of power to the 4 different loads on the PFC-16 cards. The supply voltages and load provided by 15 PFC-16 cards are the following:

- The +8 Volts supply provides about 3.4 Amps to the PreAmp Vcc load
- The -6 Volts supply provides about 0.84 Amps to the PreAmp Vee load
- The +5 Volts supply provides about 9.3 Amps to the Filter Vcc load
- The -5 Volts supply provides about 9.3 Amps to the Filter Vee load

The +8 Volt supply is a Power One model number HE12-10.2-AG linear supply that is rated for 12 Volt output at 10.2 Amps. This supply has been adjusted down to a nominal 8 Volt output by changing a feedback resistor to its uA723 regulator chip and by including two 0.5 Ohm resistors before the bulk DC bridge rectifier to reduce the bulk DC supply and thus reduce the heat dissipated by the 2N3055 pass transistors.

The -6 Volt supply is a Power One model number HC5-6/0VP-AG linear supply that is rated for 5 Volt output at 6 Amps. Turning this supply up to a nominal 6 Volt output is accomplished by changing the value of a feedback resistor to the uA723 regulator chip. Even with the output of this supply set to 6 Volts there is still about 4 Volts across its output pass transistor. The light current load on this supply probably contributes to its low noise operation with its output set up to 6 Volts.

The +5 Volt, and -5 Volt supplies are Power One model number HE5-18/0VP-AG linear supplies rated for 5 Volt output at 18 Amps. No modifications were made to the +5 and -5 Volt power supplies.

All 4 supplies are protected by input and output fuses. The input fuses are located immediately adjacent to each supply. The output fuse of the -6 Volt supply is located on that supply. The output fuses on the +8 Volt and on the +5 and -5 Volt supplies are located in a separate fuse block. The following table shows the values of the input and output fuses.

Power-One Supply	Model	AC Input Fuse	DC Output Fuse
+8V Preamp	HE12-10.2-AG	3 Amp	15 Amp
-6V Preamp	HC5-6/OVP-AG	1 Amp	3 Amp
+5V Filter	HE5-18/0VP-AG	3 Amp	15 Amp
-5V Filter	HE5-18/0VP-AG	3 Amp	15 Amp

There are separate front panel indicator LEDs and tip jack test points for each of the 4 supplies. These components and wiring are protected by separate 3 Amp pico fuses.

The +8 Volt and the +5 and -5 Volt DC outputs from the Preamp Power Supply chassis are provided by terminals on a large fuse block. The return terminals and the -6 Volt output terminal are provided on a Wieland terminal strip. These terminals are rated all rated for 30 Amps.

Each Preamp Power Supply is interlocked with the cooling air blower for the Preamplifier Box. When the air blower is running it provides a low current 12 Volt control signal to each Preamp Power Supply chassis that closes a solid state relay and thus allows AC line power to reach the Preamp Power Supply.

When the air blower is off then all AC power is blocked from reaching the Preamp Power Supplies. The solid state relay that is used in the Preamp Power Supply chassis is Crydom model CWD2425S that is rated for 240 VAC and 25 Amps.

The green-yellow safety ground wire in the Preamp Power Supply AC line cord is not tied to the Preamp Power Supply chassis. Rather the Preamp Power Supply chassis is tied to the T962 cryostat via #10 AWG wire and lugs. In turn the T962 cryostat is connected to the MINOS Hall "quiet power" ground with 3/4" copper braid.

More information about the T962 Preamp Power Supply chassis is on the web at
www.pa.msu.edu/~edmunds/LArTPC/T962/Preamp_Filter_Power_Supplies/preamp_power_supply_description.txt

Photos of the T962 Preamp Power Supply are shown in Figure 5, page 12. Additional photos are available on the web at
www.pa.msu.edu/~edmunds/LArTPC/T962/Preamp_Filter_Power_Supplies/Pictures/

Preamp Power Cable

The DC output from each Preamp Power Supply chassis is carried over to the Preamplifier Box on the T962 cryostat by a Preamp Power Cable. The Preamp Power Cable is about 25 ft long and carries the DC power from a Preamp Power Supply chassis over to either the upper or lower section of the Preamp Box on the T962 cryostat. This power cable is shown as a schematic drawing in Figure 6 on page 13.

This cable carries power to 2 different sections on the PFC-16 cards. The sections of the PFC-16 cards are the "Pre-Amplifier" and the "Filter". Each of these sections uses a Vcc and a Vee supply. There are 4 wires in the power cable for each section: a Vcc wire, a Vee wire, and two return wires. All of these wires are 14 AWG with 105 deg C insulation. Each set of 4 wires is twisted together. There is a woven plastic sleeve around the overall cable.

At the Preamp Box end of the cable there are 2 Cinch-Jones connectors, one for each section. The Vcc and Vee supply for each section are carried on one contact of the Cinch-Jones connector for that section. The return lines for that section are carried on two contacts and the alignment pin of the connector. Each contact of the connector is rated for 15 Amps.

A photo of the Preamp Power Cable is shown in Figure 7, page 14, along with a photo of the power supply with the power cable attached.

Preamp Fuse Panel

At the Preamp Box – the green box located on the T962 cryostat - the DC power is received on 2 Cinch-Jones connectors. From these connectors the power runs over to a fuse panel through 14 AWG wires. This #14 wiring is setup the same way as in the Preamp Power Cable.

There are separate Preamp Fuse Panels for upper and lower card files in the Preamp Box. Each Preamp Fuse Panel receives power from one Preamp Power Supply chassis and delivers power to 15 PFC-16 cards. Each Preamp Fuse Panel has a section for the Vcc and Vee Preamp fuses and a section for the Vcc and Vee Filter fuses.

The Preamp Fuse Panel schematic is given in Figures 8 and 9, on pages 15 and 16. All of the parts are mounted on one panel but 2 drawings are used for clarity.

Each Preamp Fuse Panel has fuses and output cables to supply power to 15 PFC-16 cards. There is a 2-1/4 Amp fuse in each of the 4 supply voltages that go to each of the PFC-16 cards. The cables that carry the power from the fuse panel to each PFC-16 card are made with 22 AWG wire. Each PFC-16 card has one cable for its "Preamplifier" power and another cable for its "Filter" power.

The connectors that plug these cables into the PFC-16 cards are made with 6 position AMP MOD IV housings and AMP high pressure contacts. The contacts are AMP/Tyco part number 1-87309-4 and Newark stock number 90F3791. These contacts are rated for 3 Amps each. The current rating specification for these contacts is available from AMP/Tyco web site at:
http://catalog.tycoelectronics.com/TE/bin/TE.Connect?C=1&PN=1-87309-4&M=BYPN&LG=1&I=13

Figure 10 on page 17 shows a photo of one of the 2 Preamp Fuse Panels before it was installed in the Preamp Box.

PFC-16 Cards

The PFC-16 cards receive "already fused power" on 2 connectors. Each connector is a 6 pin header of 25 mil square pins. One connector is for the Preamp power and the other connector is for the "Filter" power.

Once the power is on a PFC-16 card, the card is protected from spikes and reverse polarity by a Transient Voltage Suppressor on each of the 4 supplies. Each supply is also cleaned up by bulk Aluminum Electrolytic and Tantalum capacitors before they reach the actual electronics components on the card.

The PFC-16 card is shown in Figure 11 on page 17. You can see where the power is received on the PFC-16 card along the left-hand edge in this photo.

The power connectors on the PFC-16 card are rotationally symmetric, i.e. if one is plugged in rotated by 180 deg it makes no difference. If a connector is plugged in offset by one pin then it will directly short circuit the supply and blow the 2-1/4 Amp fuse (the card itself will not see any significant supply voltage). If the connector for the Preamp supply is exchanged with the connector for the Filter supply nothing is damaged. The PFC-16 card will not work well with these connectors interchanged but nothing is damaged.

Gerber files of the layers on the PFC-16 card that carry power can be made available for review. The power is carried on power planes so there is not really an issue about sufficient trace width to match the 2-1/4 Amp fuses that protects the card.

Each PFC-16 card has 4 banana plug pins that connect the ground plane of the card to the cryostat vessel which is the signal ground for the LArTPC signals. You can see these banana plugs in the photo of the PFC-16 card in Figure 10. It is only through these banana plugs the the Preamp Power Supply return lines are tied to ground.

VME Readout and DAQ System

The T962 VME Readout crate is located in the T962 DAQ relay rack, which in turn is located on the upper MINOS platform adjacent to other realy racks belonging to MINOS. The T962 VME Readout rack is within 10-ft of the T962 cryostat.

The VME crate used by the T962 readout is a commercial unit made by Wiener. It is their type UEV 6023 crate with their type UEL 6020 LX fan tray and type UEP 6021 power supply chassis. This equipment has the TUV and IEC regulatory certificates. This crate holds electronics cards that are 6U tall and it has a VME64-X type backplane. No power is brought out from this VME crate to an external load. Besides its power cord, the following connections are made to this crate:

- Optical connection between the Bit-3 card in slot #1 and the DAQ computer
- TTL level trigger signal to the SCLD_Sub card in slot #3
- 480 analog input signals to the 15 ADF-2 cards (via the 3 ATC cards) from the preamplifiers on the T962 cryostat

All of these connections are "signal level" connections and none of them can provide a substantial amount of current to anything outside of this crate.

There are four types of cards used in this VME crate: the Bit-3 VME Interface, the ATC, the ADF-2, and the SCLD_Sub. Each of these is described in the following sub-sections.

Bit-3 VME Card

The BIT-3 VME interface card is a SBC Bit-3 model 618. I believe that this card uses only +5V from the VME bus. Only one of these commercially manufactured 6U cards is used in this VME crate. Note that this commercial card is now supplied by GE-Fanuc and is currently called model 618-3. For more details about this card see: http://sbs.com/products/371

ATC Cards

This crate uses 15 ATC cards which plug into the back side of the VME crate backplane. ATC stands for "ADF Transition Card". The ATC does not make any connections to the crate's power buses. No power is brought onto the ATC card. The ATC card only makes input and output connections to signal cables. There are no active parts on the ATC card - it holds only connectors.

ADF-2 Cards

In this crate there are 15 ADF-2 cards. ADF-2 stands for "ADC and Digital Filter version 2". These cards are in use by the D-Zero calorimeter; the particular cards being used for T962 are spares on loan from the Michigan State D-Zero group, and are unchanged from those in use at D-Zero.

Each ADF-2 card makes power supply connections to the: +3.3V, +5V, +12V, and -12V VME backplane busses. The number of pins used by the ADF-2 card to make connection to each of these busses is shown in the following table, along with the size of the fuse used on that bus.

Backplane Bus Connection	Number of Pins used for connection	Fuse Rating
+3.3 V	10 pins	3 Amps
+5.0 V	6 pins	3 Amps
+12 V	1 pin	2 Amps
-12 V	1 pin	2 Amps
Ground	47 pins	

As they are brought onto the ADF-2 card, each power supply bus passes through a fuse before it reaches any other components. All pins used to bring a given power supply bus onto the ADF-2 card are connected to a small isolated section of a circuit board power plane. The only other connection to that isolated section of power plane is the input to that supply's fuse. After its fuse, each power supply bus has a transit voltage suppressor and a bulk filter capacitor before entering the electronics area of the card. The fuses used are Littelfuse Part No. R154003T.

Copies of the actual films used to manufacture the ADF-2 circuit can be seen on the web in the following directory: www.pa.msu.edu/hep/d0/ftp/run2b/l1cal/hardware/adf_2/manufacturing/ . The table below describes what is shown in the available film files. These films can be studied to verify that each power supply bus passes through a fuse before connecting to any other components on the ADF-2 card.

Filename	Shows the power bus connection for
adf2_film13_l3.gif	shows one of the two equivalent Ground planes
adf2_film12_l4.gif	+5V is collected from 6 pins and routed to its fuse by the strip along the right hand edge of the card
adf2_film07_l9.gif	+3.3V is collected from 10 pins and routed to its fuse by the strip along the right hand edge of the card
adf2_film04_bot.gif, adf2_film05_l11.gif	The +12V and -12V VME Buses are routed directly to their fuses by thick traces at the right hand side of these layers. Each bus is carried by a thick trace on each of these two layers.

A photo of the ADF-2 card is shown in Figure 12 on page 18. The 4 power input fuses on the ADF-2 card can be seen along the top edge in the photograph, near the VME backplane connector.

SCLD_Sub Card

The SCLD_Sub card used in the T962 DAQ system is a "substitute" for the real SCLD card, which was designed and manufactured by Denis Calvet of Saclay for the D-Zero calorimeter readout. This SCLD_Sub card was a prototype (not a spare) for the D-Zero system. The card's name stands for "Serial Command Link Distributor". Just one SCLD_Sub card is used in the T962 DAQ crate. The SCLD_Sub is a 6U VME card.

The SCLD_Sub card receives both +5V and +3.3 Volts from the VME backplane. The following table shows the number of backplane pins that are used to bring each power bus onto the SCLD_Sub card and the size of the fuse used in the bus. The fuses used are Littelfuse Part No. R154003T. The power from the backplane passes through a fuse before reaching any other part of the SCLD_Sub card.

Backplane Bus Connection	Number of Pins used for connection	Fuse Rating
+3.3 V	3 pins	3 Amps
+5.0 V	3 pins	3 Amps
Ground	16 pins	

A photo of the SCLD_Sub card is shown in Figure 13 page 18. Along the backplane connector edge of the SCLD_Sub card near the bottom of its P1 connector you can see the fuses for the 2 power busses that are brought onto the card.

The SCLD_Sub card makes no connections to the VME backplane except for +3.3V, +5V, and ground. The only other connections to the SCLD_Sub card are: one fiber optic and one BNC TTL signal on its front panel and six LVDS signals from its backplane P0 connector.

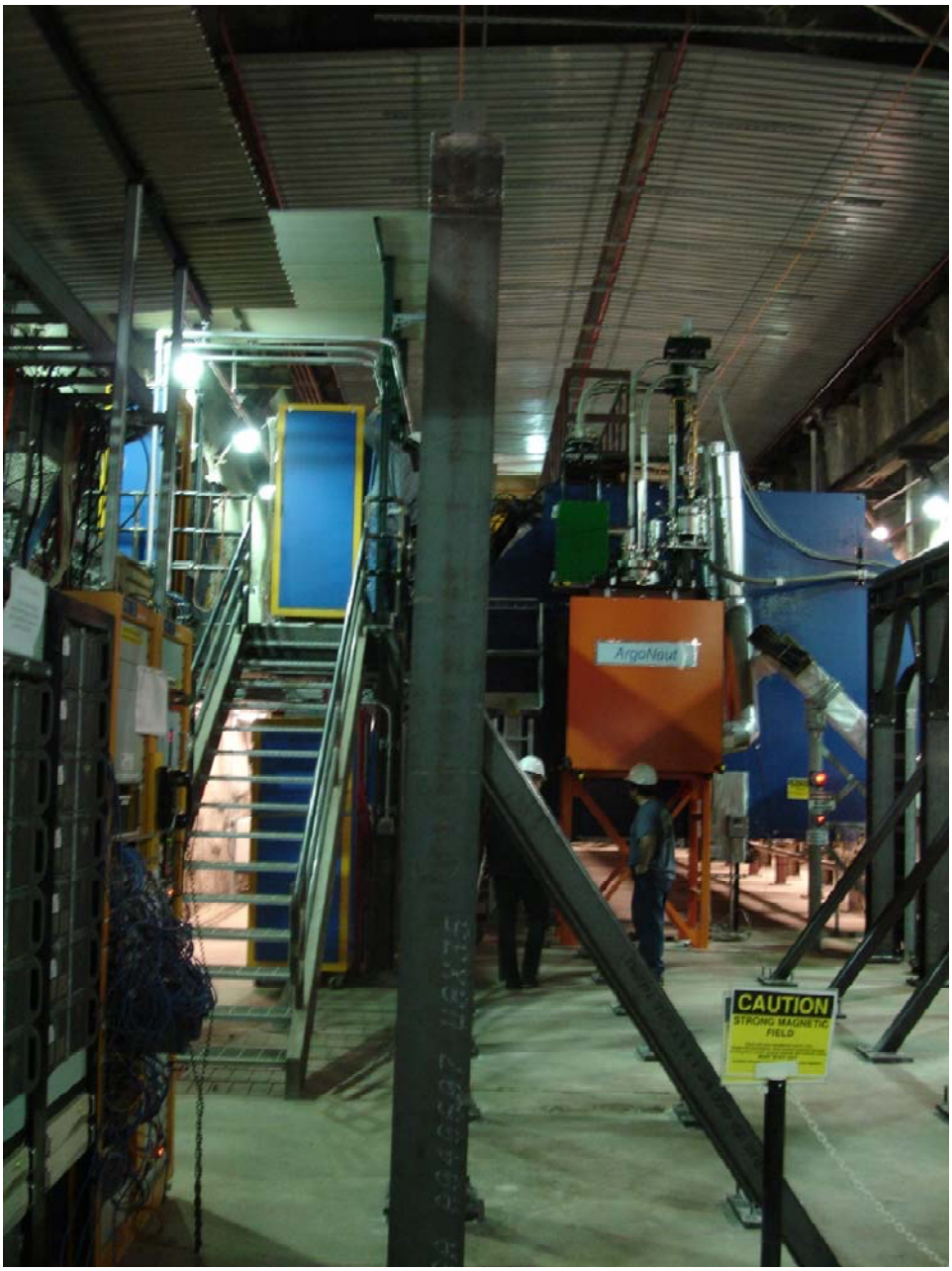
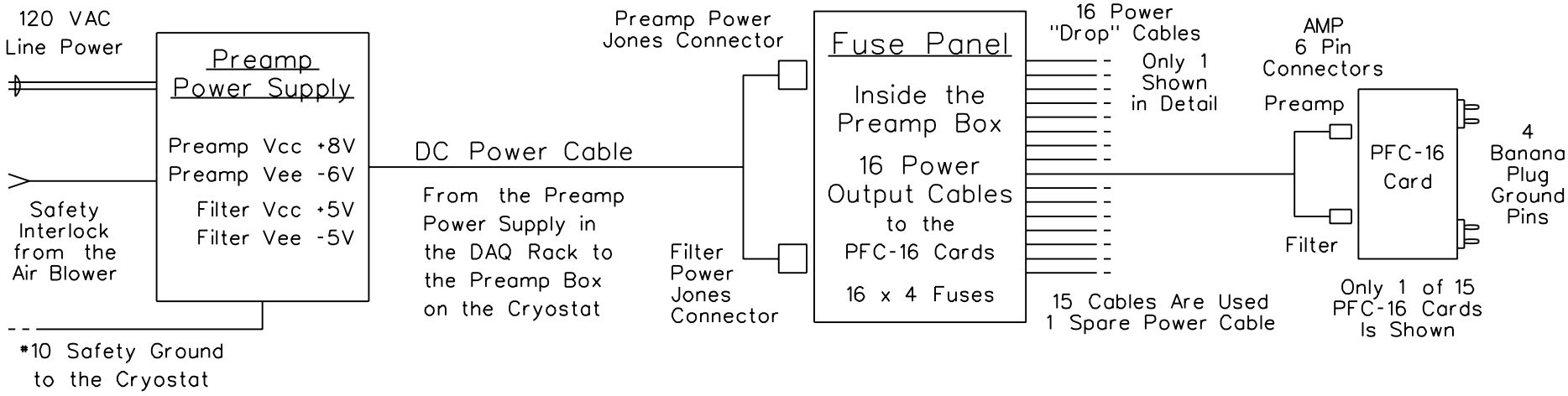


Figure 1: The ArgoNeuT detector, within it's orange containment tub, in front of the MINOS Near Detector (blue steel). The green pre-amp box sits above the cryostat, which is entirely within the orange tub. The T962 Readout and DAQ Relay Rack is the yellow-framed rack seen at left, at the top of the stairs, on the upper level. The post in the near foreground is part of the Minerva detector support structure.

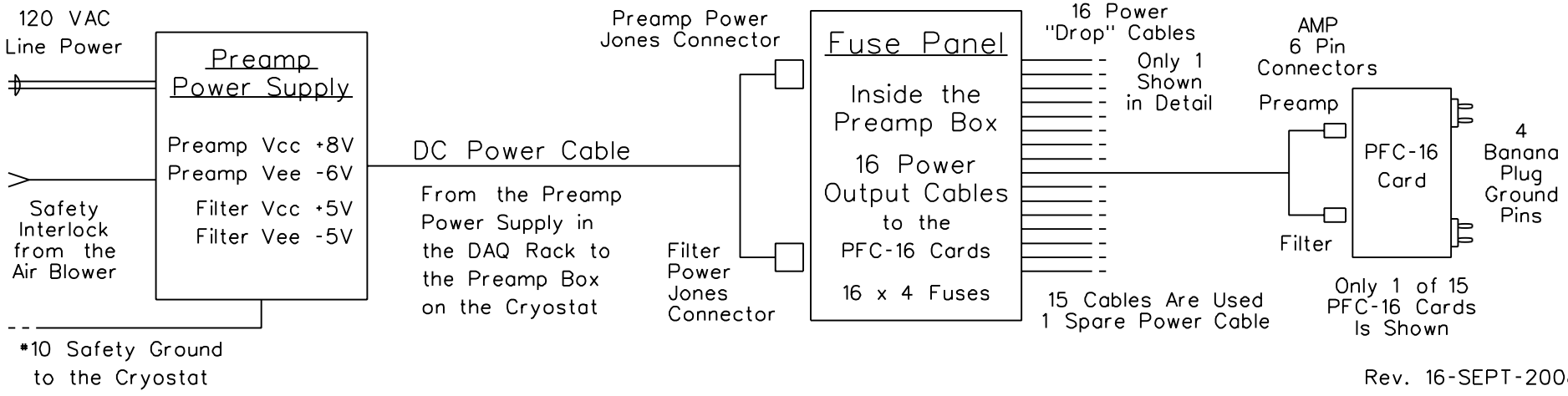
T962 LArTPC Preamp Power System

General Block Diagram

Power for the Preamp Box Upper Card File

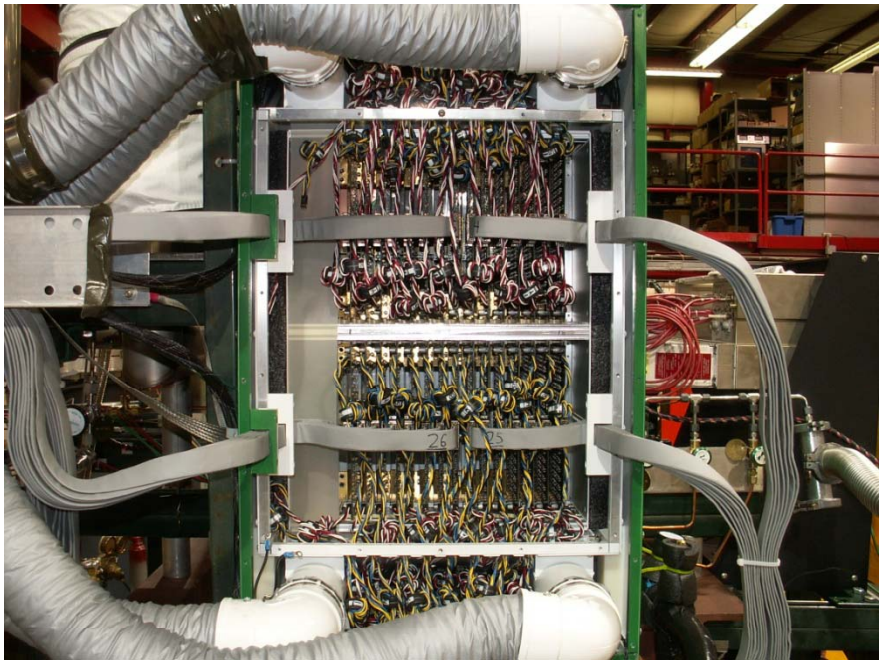


Power for the Preamp Box Lower Card File

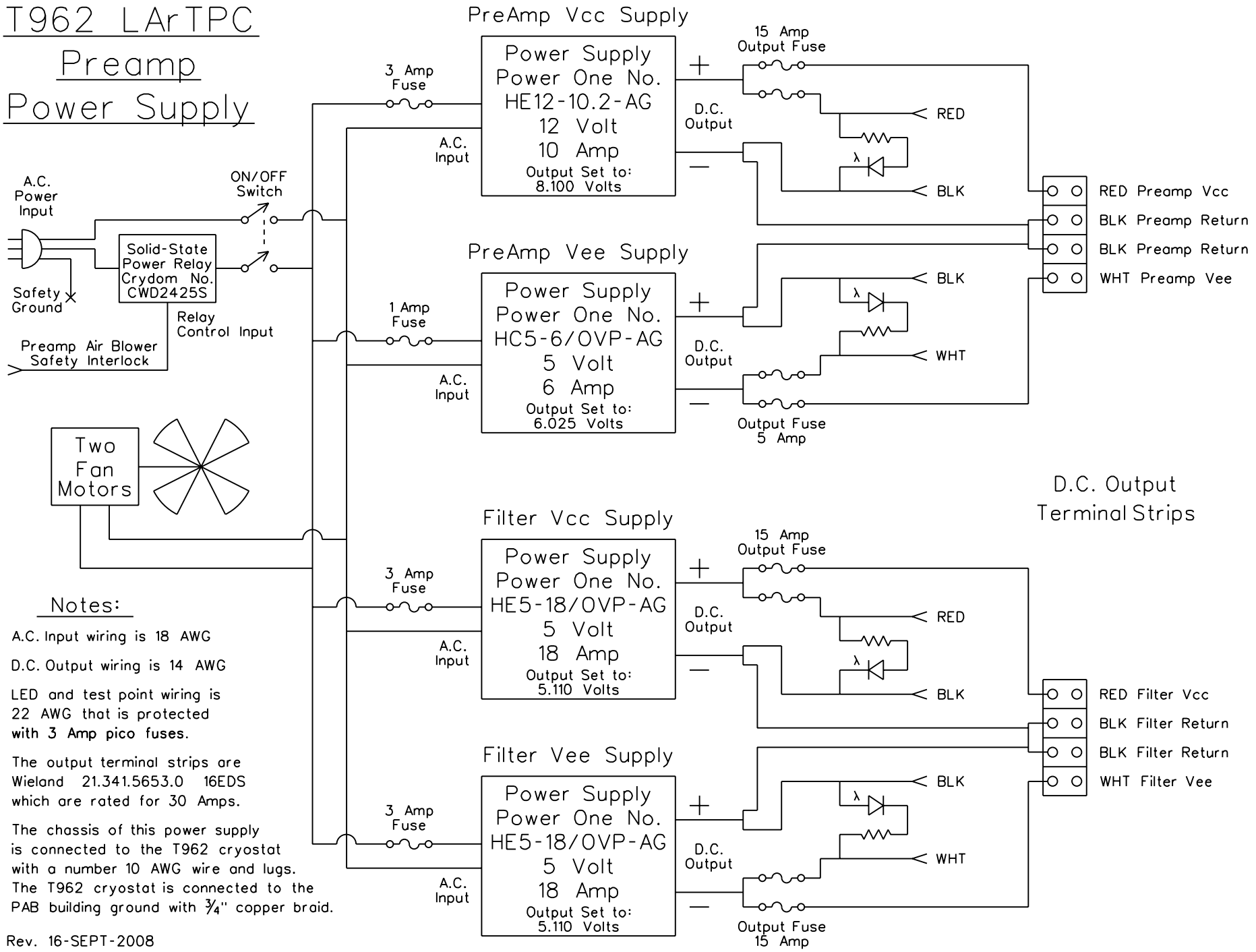


Rev. 16-SEPT-2008

Figure 3: the green pre-amplifier box. Both views are from the front. The upper photo is of the empty box, giving a view of the signal cable feed-through (from the cryostat) and the two card files. The lower photo shows the box with all the PFC-16 cards. The grey cables carry readout signals to the VME crate. The pre-amp power cables enter from the left side (black). The hoses carry cooling air from fans located in the relay rack.



T962 LArTPC Preamp Power Supply



Notes:

A.C. Input wiring is 18 AWG

D.C. Output wiring is 14 AWG

LED and test point wiring is 22 AWG that is protected with 3 Amp pico fuses.

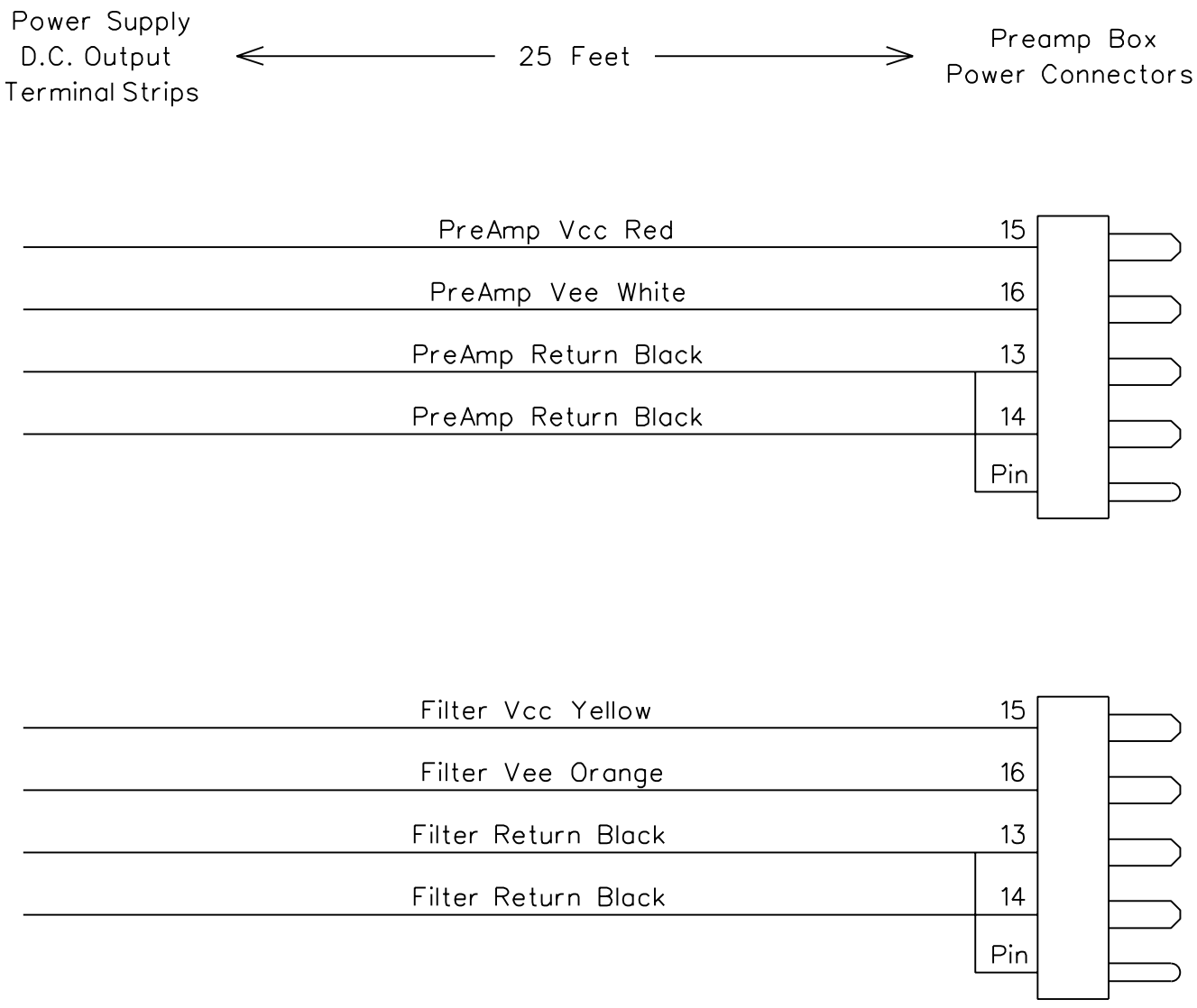
The output terminal strips are Wieland 21.341.5653.0 16EDS which are rated for 30 Amps.

The chassis of this power supply is connected to the T962 cryostat with a number 10 AWG wire and lugs. The T962 cryostat is connected to the PAB building ground with ¾" copper braid.

Rev. 16-SEPT-2008

Fig 5: Front and inside views of the Pre-amplifier Power Supply

T962 LArTPC
Preamp Power Cable



These cables are made with number 14 AWG wire. Each set of 4 wires is twisted together and the overall cable is covered with a woven sleeving.

The connectors are Cinch Jones P2404 15 Amps per contact

Rev. 11-SEPT-2008

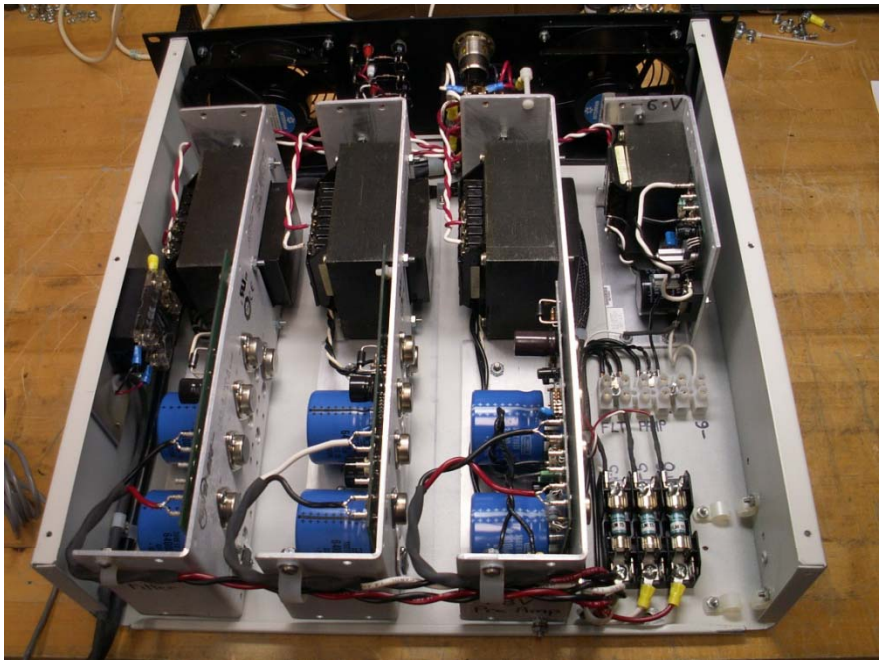
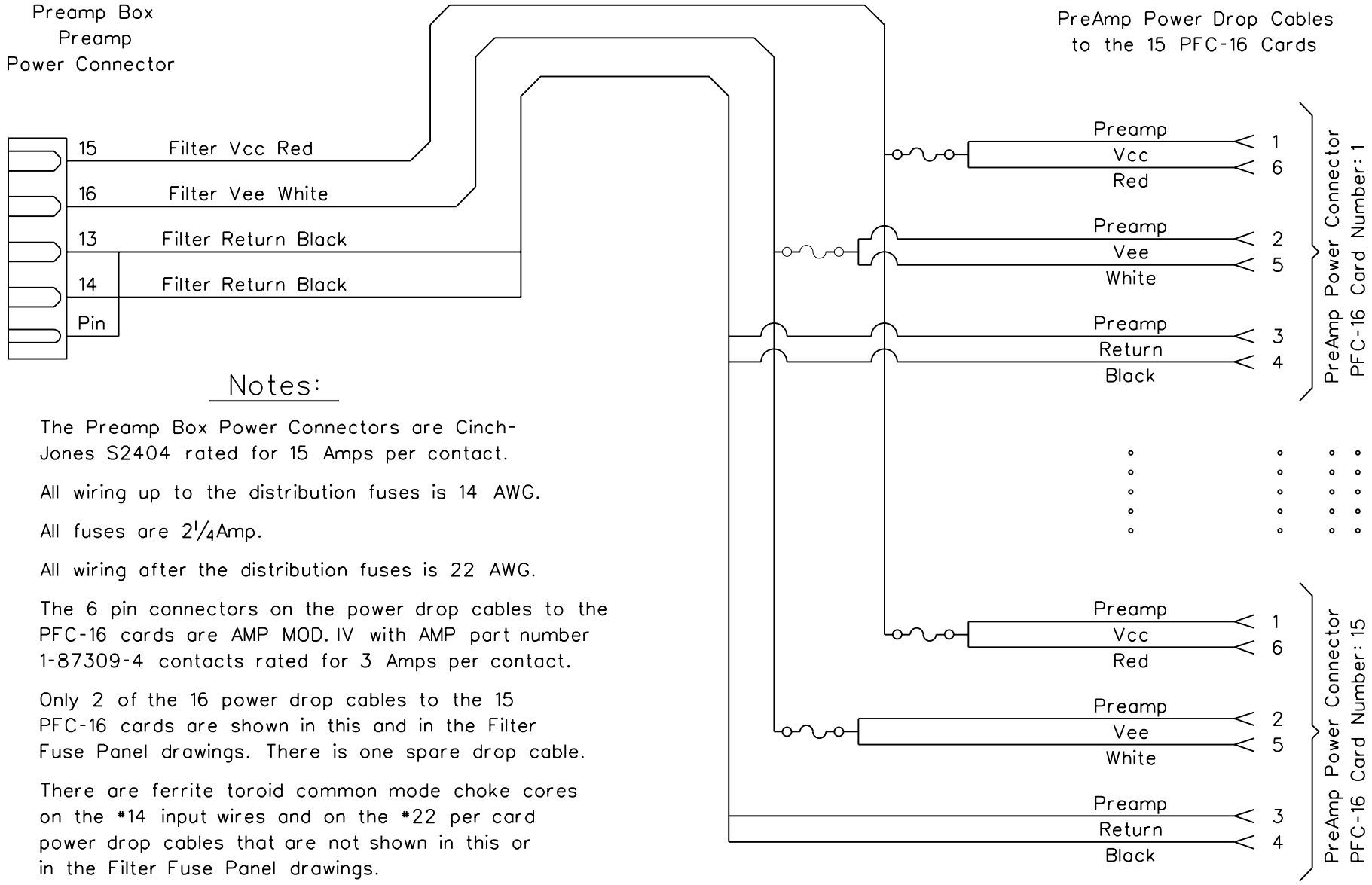


Fig 7: Above, the pre-amp power cable; below a top inside view of the Pre-amplifier Power Supply, with the power cable exiting at lower left.

T962 LArTPC Preamp Fuse Panel - Preamp



Notes:

The Preamp Box Power Connectors are Cinch-Jones S2404 rated for 15 Amps per contact.

All wiring up to the distribution fuses is 14 AWG.

All fuses are 2¼Amp.

All wiring after the distribution fuses is 22 AWG.

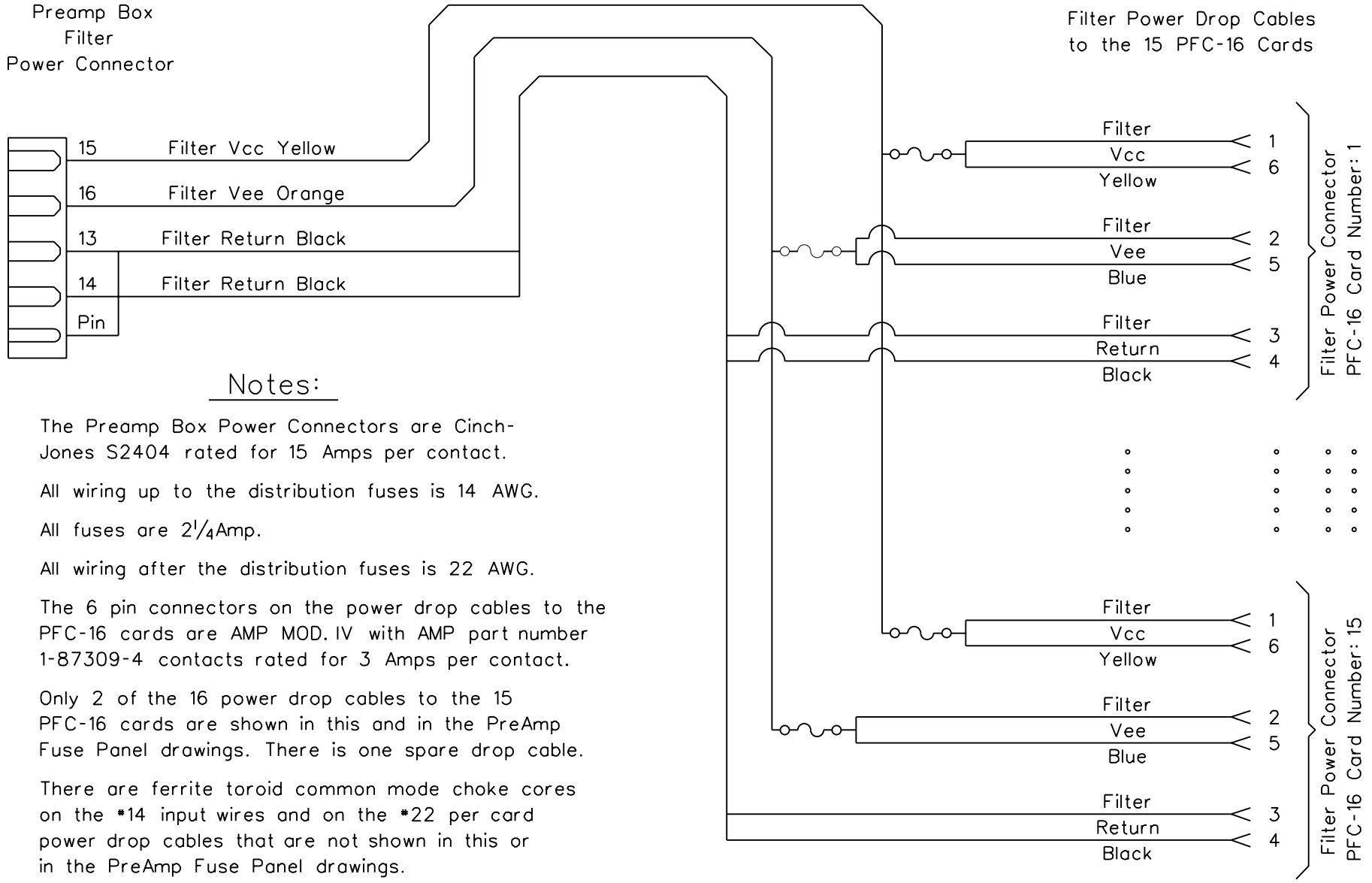
The 6 pin connectors on the power drop cables to the PFC-16 cards are AMP MOD. IV with AMP part number 1-87309-4 contacts rated for 3 Amps per contact.

Only 2 of the 16 power drop cables to the 15 PFC-16 cards are shown in this and in the Filter Fuse Panel drawings. There is one spare drop cable.

There are ferrite toroid common mode choke cores on the #14 input wires and on the #22 per card power drop cables that are not shown in this or in the Filter Fuse Panel drawings.

Rev. 11-SEPT-2008

T962 LArTPC Preamp Fuse Panel - Filter



Notes:

The Preamp Box Power Connectors are Cinch-Jones S2404 rated for 15 Amps per contact.

All wiring up to the distribution fuses is 14 AWG.

All fuses are 2¼Amp.

All wiring after the distribution fuses is 22 AWG.

The 6 pin connectors on the power drop cables to the PFC-16 cards are AMP MOD. IV with AMP part number 1-87309-4 contacts rated for 3 Amps per contact.

Only 2 of the 16 power drop cables to the 15 PFC-16 cards are shown in this and in the PreAmp Fuse Panel drawings. There is one spare drop cable.

There are ferrite toroid common mode choke cores on the #14 input wires and on the #22 per card power drop cables that are not shown in this or in the PreAmp Fuse Panel drawings.

Rev. 11-SEPT-2008

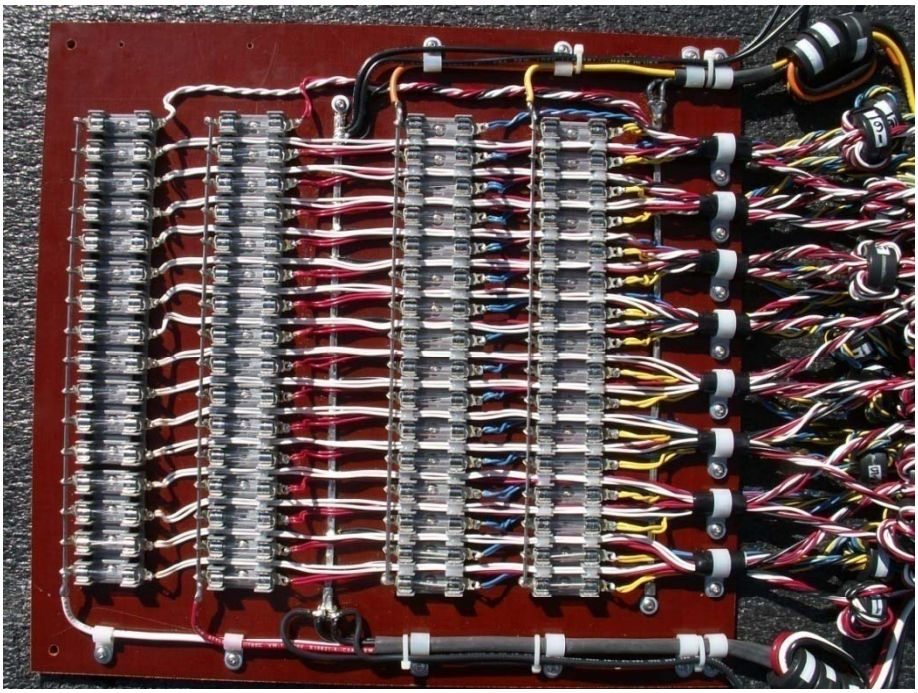


Fig 10: the pre-amp power fuse panel, which is located inside of the pre-amp “green” box

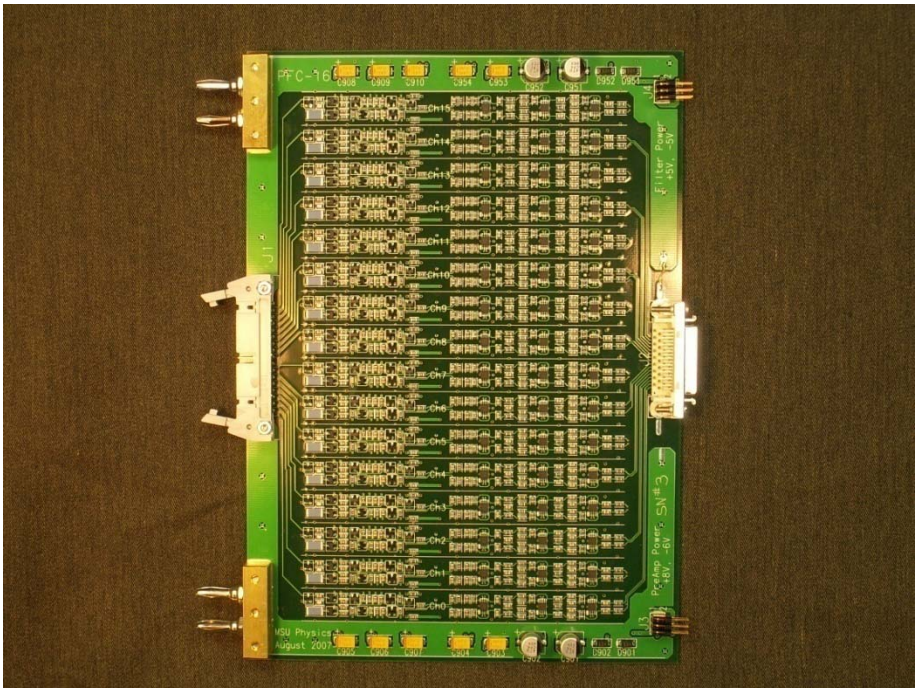


Fig 11: the PFC-16 card

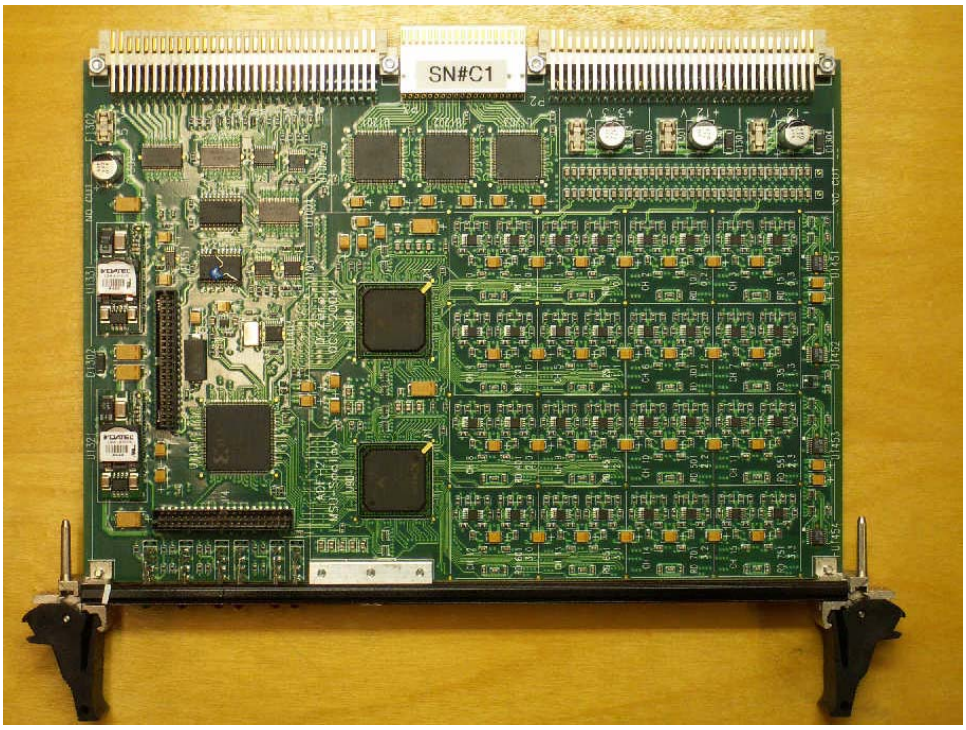


Fig 12: the ADF-2 card

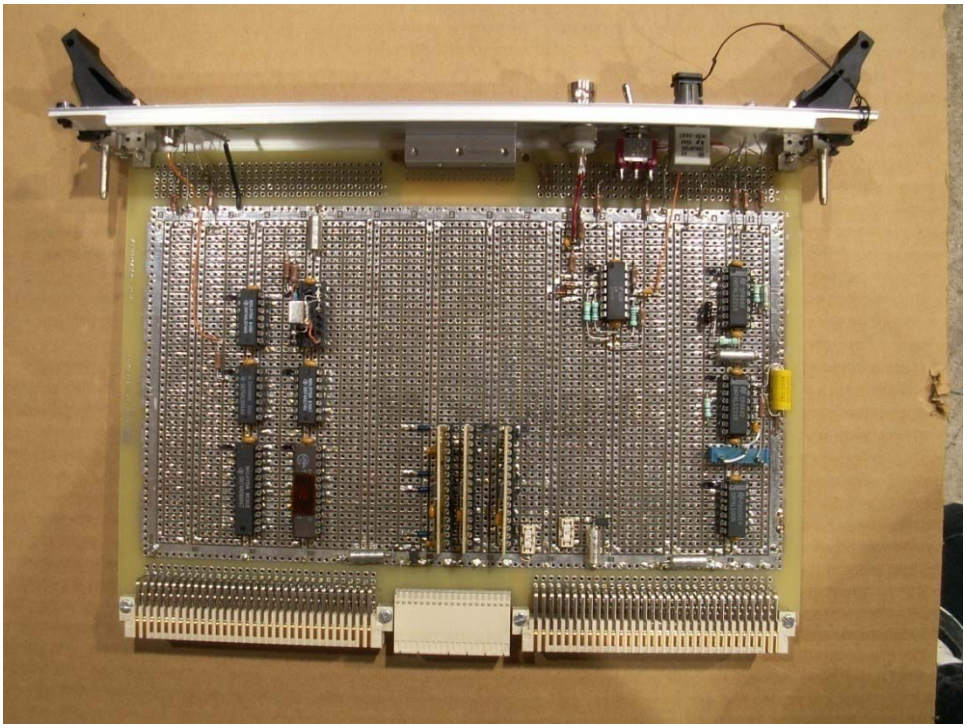


Fig 13: the SCLD-Sub card

ELECTRONICS PORC REVIEW – REVIEWER COMMENTS

QUESTIONS FROM REVIEWER D HUFFMAN -

1. The output fusing seems to be a bit on the high side. What if the currents are near the fuse rating, does the output pass transistor overheat? The modification of the HE12-10.2-AG would seems to indicate some concerns for the pass transistors well-being.
2. Is it common practice to connect the safety ground as indicated in the write up?

RESPONSE FROM D. EDMUNDS –

The first comment is in reference to the +8V supply for the preamp section of the PFC-16 cards. I completely agree that using a 15 Amp fuse on a circuit where you expect only a 3.4 Amp load is on the "high side". Even though the wire sizes are large enough to safely carry 15 Amps this is not the correct size fuse to use in this application.

If you agree, I think it would be best if I change this fuse from 15 Amps to 10 Amps. Using a 10 Amp "DC Output Fuse" on the +8V preamp supply will make the fuse size both less than the rated output current capacity of the supply itself and a 10 Amp fuse is well below the rated current carrying capacity of the DC wiring from this supply.

If you agree, then today (March 3, 2009) I will change the safety document for the preamp power supply system to specify a 10 Amp fuse for the DC Output Fuse on the +8V preamp supply. This document is:

http://www.pa.msu.edu/~edmunds/LArTPC/T962/Safety_Review/t962_preamp_safety_review.txt

I will also change the specified value of this fuse to 10 Amps where it is shown on the related drawings. I will obtain 10 Amp fuses and physically chance the +8V DC Output fuse from 15 Amp to 10 Amp on my next trip to Fermi.

I have run the modified Power One model HE12-10.2-AG supply at its full rated current and the pass bank transistors do not get too hot to touch. The pass bank uses 4 2N3055 transistors.

In response to question 2, I describe the purpose behind the design. As described in the safety review document for the preamp power supplies and as shown in the related drawings the green-yellow safety ground wire in the line cord for these supplies is not connected to the chassis that holds these power supplies. Rather a safety ground for these supplies is provided by connecting each power supply chassis to the T962 cryostat via a #10 wire and finally connecting the T962 cryostat to the building ground.

The intent of these connections is to reduce the ground loop current circulating between the supplies and the cryostat while still providing a good safety ground for the supplies. During operation the chassis of these power supplies is also grounded by being screwed into the DAQ rack and the DAQ rack itself is connected via a separate #10 wire to the cryostat.