MUON SPIN RESONANCE SOLENOID

for

TRIUMF

JOB NO. 2282 **JUNE 1988**

CRYOGENIC

CRYOGENIC

Our ref: J.2282
TRIUMF

NOTE

The switch has been removed from the cryomagnet circuit, and the current leads have been permanently mounted in the cryostat.

Please bear these points in mind when reading the manuals and when operating the system.

WARNING

On no account apply rotational force to the current leads as this may break the joints to the cryomagnet.

NOTE

Shim coils disconnected to reduce the heat load into the He bath.

Jan. '03
BH

CONTENTS

Our ref: J.2282
TRIUMF

APPENDICES

FIGURES

DESCRIPTION OF SYSTEM

General

The muon spin resonance magnet for TRIUMF is a superconducting solenoid capable of producing a central field in excess of 7 Tesla, within a region of homogeneity better than 1 part in 10^5.

The homogeneous region is a cylinder coaxial with the solenoid, of diameter 25mm and length 10mm.

The solenoid is bath cooled in liquid helium, with nitrogen cooled radiation shields. The reservoirs give a hold time for helium in excess of 200 hours and, for nitrogen, in excess of 130 hours.

Solenoid

The solenoid consists of two separate coils. The inner coil is wound with 8,352 turns of 0.6mm wire and 16,512 turns of 0.5mm wire. The outer coil is wound with 17,998 turns of 0.5mm wire. The ratio of copper to superconductor in the 0.6mm wire is 1.35:1. The ratio in the 0.5mm wire is 1.4:1. The turns are impregnated with epoxy resin giving a very strong and reliable structure which is training free.

The complete solenoid is shimmed with two sets of four 25-turn saddle coils to produce the required homogeneity.

The separate coils are formerless (i.e. wound on a removable mandrel) and are mounted concentrically on the end plates of the aluminium helium jacket.

The 7 Tesla central field is achieved with a magnet current of 73.35 Amps. The maximum current the solenoid should be operated at is 75 Amps.

The solenoid has a self-inductance of approximately 140 Henries.

Cryostat - (refer to the G/A drawings provided).

The cryostat consists of two main cylindrical structures, the lower cylinder housing the solenoid, the upper housing the reservoirs.

The main vacuum jackets are welded aluminium structures. 12 off $^5/_{16}$"-18 U.N.C. tapped holes on a 254mm PCD are provided on each of the bottom vacuum can end plates to facilitate mounting to the bore of the solenoid. There are a set of scribed lines on the end plates to which the solenoid is aligned to +/- 0.5mm. The "warm" seals are nitrile rubber except at the top plate where indium is used. Silicone rubber is used where vacuum integrity is not so important in a potentially cold seal, e.g. on the top castle.

The demountable cold seals are all indium.

Spring washers are used on the top plate indium seal to counteract "creeping".

The NW40KF evacuation port, vacuum space over-pressure relief and NW25KF vacuum gauge port are all let into the base of the top vacuum can. A high vacuum valve and vacuum gauge are provided.

The helium reservoir has a volume of 56 litres and is of welded aluminium construction.

The helium reservoir is suspended from the system top plate by the GRP neck tube. This is the only structural support for the reservoir and is completely adequate for most uses of the system, but does mean that the system should not be operated at more than 30° from the vertical and should not be subjected to handling shocks at more than 5° from the vertical.

The GRP neck tube carries the removable solenoid current leads, the fixed solenoid protection leads, the fixed x and y shim coil leads, the syphon guide tube, and the level gauge guide tube. These pass to the bottom of the helium reservoir. The top 160mm of the neck tube carries six gas cooled radiation baffles which transfer radiant heat down the neck to the upward-flowing gas stream.

The current leads are made from $^3/_8$" x 20 gauge tube, copper from the base to the top of the helium reservoir, and brass from the top of the helium reservoir to the top castle. The leads are paralleled on their copper sections with Nb_3Sn tape and optimised for 75 Amps.

The leads are removable from the cryostat - to reduce boil off when the solenoid is running in persistent mode - through use of screw connections to the leads from the solenoid.

The protection leads. Four 4mm x 20 gauge stainless steel protection leads are permanently fixed in the neck tube to provide connections to the external thyristor protection unit.

The shim leads. Three 3mm x 20 gauge brass shim coil leads are permanently fixed in the neck. These provide connections to the orthogonal x and y shim saddle coils - one to each of the coils, plus one common. Current input is via multipin connection 'B' in the top castle. See Appendix 'D' for pin connections.

The syphon guide tube. This is a $^5/_8$" OD stainless steel tube fitted with a 20° cone coupling at the bottom, to mate with a standard syphon. Two side slots are provided in the tube so that when the syphon is lifted by 40mm or more the cones are disengaged and a helium refill may take place without warming the solenoid unduly - see "Helium Refill Procedure".

The distance from the top of the top castle to the bottom of the cone coupling is 940mm.

The cone coupling feeds into the syphon extension tube, which is a $^3/_{16}$" copper tube that is taken to the very bottom of the solenoid helium jacket. This ensures the efficient cooling of the system using the enthalpic content of the cryogens.

The liquid helium level gauge probe. This is a demountable probe. It should be fixed using the knurled O-ring compression cap so that it is fully pushed home. The operation of the probe is described in the DLG210 manual. See also Installation Procedure.

The helium exhaust port. This is a NW40KF flange let out of the top castle. Gases evolved during cooldown and subsequent operation escape through this port.

The helium exhaust over-pressure relief valve. This valve is connected via an NW40 'T' piece to the helium exhaust port (see Installation Procedure). It provides an alternative escape route for gases blown off during a quench should the pressure along any helium collection hose rise above the set pressure of 5 psi above ambient. This valve must be included if the helium exhaust is not venting directly to the atmosphere.

The valve is spring loaded and will automatically reset itself after operation in any attitude. The valve is not intended to be fully vacuum tight, but is gas tight in its normal operation.

The liquid nitrogen reservoir. This is a welded aluminium anular can with a volume of 31 litres. It is supported above the helium reservoir and around the neck tube by two stainless steel pillars and the stainless steel fill tube.

The fill tube is also used for the liquid nitrogen level probe and for nitrogen exhaust.

The liquid nitrogen level probe. This is a ¼" GRP tube fitted with 5 platinum resistance thermometers, each having a room temperature resistance of 100 ohms and a liquid nitrogen temperature of 19 ohms. The probe runs to the base of the nitrogen reservoir and is secured in a combined instrumentation and fill castle on the top plate. The resistors are wired into a 10-pin connector in the castle.

The radiation shields. These are a set of aluminium shells that surround all the "4 Kelvin" parts of the system.

These shells are maintained at a temperature of less than 100 Kelvin during normal operation so that radiation from 300 Kelvin is intercepted before reaching the lower temperature parts. The magnet tie rods and GRP neck are also grounded to these shields to intercept most of the conducted heat flow to the helium jacket and reservoir.

The shields are conduction cooled by the liquid nitrogen reservoir.

The superinsulation. Surrounding the radiation shields are some layers of superinsulation which reduce the heat load on the radiation shields.

The solenoid tie rods. The solenoid is held in place inside the cryostat by a set of titanium tie rods. These are capable of restraining a load of 250 kg safely in any direction.

They will withstand shocks to the system during handling of up to 3 g.

The helium jacket heaters. There are two pairs of 20 ohm heaters in the system attached to the bottom of the helium jacket. These are capable of generating approximately 40 Watts each when energised with 1 Ampere. On no account should this current be exceeded as damage to the heaters and/or their leads may result.

The heaters may be used to ensure that there is no liquid nitrogen left in the bottom of the helium jacket after a precool.

See Instrumentation Ports Pin Out Appendix 'D'.

See Cooldown Procedure.

The thermometers. A set of 6 thermometers has been mounted in the system.

The thermometers are 4 terminal rhodium iron resistance types that cover the temperature range 1.5K to 300K with good precision. The system is supplied with a DTG200 which gives a temperature reading directly in Kelvin. The DTG unit is calibrated to one sensor in the system only (channel 1), but will read to within several Kelvin on all the others. The degree of error in the DTG reading for each of the thermometers is given in Appendix 'C'.

See Fig.5 for the Instrumentation Ports Pin Out.

If the DTG box is not used a bias current of not more than 10 ma should be used to measure the thermometer resistance.

See below and the G/A drawing for the positions of the thermometers.

Sensor		DTG Channel
A	Solenoid helium jacket top	1
B	Solenoid helium jacket bottom	2
C	Helium reservoir bottom	3
D	Nitrogen reservoir bottom	4
E	Base of top vacuum can shield	5
F	Base of bottom vacuum can shield	6

INSTRUMENTATION

Introduction

The solenoid is serviced by a set of electronic instruments which monitor and control various system parameters (magnet current, helium level, etc.). These instruments are linked by a set of interlocks which are intended to prevent unsafe operation of the system. See Appendix 'A' for Interlock Table, and Fig.6 for Schematic Diagram.

The electronics allows monitoring and control at both a LOCAL and REMOTE station.

Control is transferred between the two stations from the LOCAL end only.

When control is transferred the REMOTE station will adopt the fail safe, zero solenoid current mode so that the state of the system is known.

The LOCAL station is comprised of the following instruments/units plus inter-connecting cables.

PS120C-H	High voltage superconducting magnet power supply.
DLG210	Liquid helium level gauge.
DTG200	Temperature indicator.
NLG	Nitrogen level gauge
Penning 505	High vacuum gauge
Metrolab PT3020	High precision NMR Tesla meter
Metrolab 2031	Combined multiplexer and amplifier for PT3020

For all the above see also the appropriate manual.

A junction panel is also provided at the LOCAL station for interconnecting the various units to the REMOTE station.

All the units run on 117 Volts except the PS120C-H which requires 208 Volts.

All the monitoring instruments are provided with a minimum of 4 metres of cable from the cryostat to the readout. See Appendix 'B' for the cable specifications.

The LOCAL station allows control of the solenoid magnetic field via the PS120C-H power supply. During cooldown and subsequent operation of the system the temperatures of various critical points in the system may be monitored using the DTG200. See Thermometer and DTG Sections.

The degree of vacuum in the system interspace is monitored by the Penning 505 vacuum gauge. In addition this gauge is interlocked to the power supply such that a pressure of greater than 2×10^{-4} mbar will cause the power supply to ramp the solenoid current to zero and an alarm to be triggered at the REMOTE station.

The levels of liquid helium and liquid nitrogen in the system are monitored using the DLG210 and the NLG, respectively. When the helium level falls below 80mm, or the nitrogen level below 20%, alarms are triggered at the REMOTE station. If the helium level falls below 25mm then the solenoid current is ramped down and the REMOTE alarm is sounded.

The power supply will also ramp the current to zero at the maximum rate if either of the 'EMERGENCY STOP' buttons are pressed.

The power supply is "tripped" by certain false external interlocks or by solenoid over-voltage due to a quench.

Control is transferred to the REMOTE station by pressing the REMOTE button on the power supply. Control can only be transferred at this point.

The REMOTE station consists of a single custom-built rack mountable annunciator panel, and a TANDON PC-X personal computer. These may be mounted up to 40 metres away from the LOCAL station.

All functions of the NMR Teslameter and the PS120C-H are available at the computer, once control has been transferred to the REMOTE station.

Four alarm lights show on the annunciator panel : vacuum trip, helium warn (indicating low helium level), helium trip, and nitrogen warn (labelled NITROGEN TRIP, but indicating low nitrogen level). In addition there is an audible warning device which will sound on any of these conditions. This may be silenced. A general indication of the solenoid status is provided by the illumination of either the "CLEAR" or "TRIPPED" lamps.

PS120C-H Power Supply

This is a constant current power supply specifically designed for superconducting magnets. Its maximum output is 120 Amps, with a voltage compliance of +/- 15 Volts. It has a built in ramp generator and protection circuitry which will protect the power supply and the solenoid in the event of a quench.

Ramping is only possible when the junction panel and annunciator panel are connected (see page 14) and all interlocks are true.

Transferring control from one station to the other is only possible when ramping in inactive.

Please see the PS120C-H manual for detailed operational instructions, and for details of the back panel connections.

Please see Electronics Installation Procedure in this manual for connecting the power supply to the solenoid and interlocks.

The DLG210 Liquid Helium Level Gauge

This is an instrument which biases and monitors the liquid helium level probe in each solenoid's helium reservoir. The helium level is calculated and displayed in millimetres on the front panel.

The liquid helium level gauge in the reservoirs, when properly installed (see Installation Procedure) will read 10mm for each 1.33 litres of volume. The reservoir is full when the gauge reads 460mm.

NOTE there may be a small zero error of around 10mm. This may be nulled out. See the DLG manual.

PLEASE NOTE that there are two settings for rate of reading of the DLG - MAX and MIN. See manual for details.

It is important that the MIN function is selected during operation of the solenoids, to minimise helium boil off.

The MAX rate should be used when filling.

PLEASE NOTE that the switch marked 'RELAY' should always be in the 'AUTO' position, since the Auto-Refill function is used as a warning signal to the REMOTE stations.

Interlocks. The helium level gauge has two levels of interlock :-

i) The warning level, which uses the auto-refill function and has been set at 80mm.

ii) The trip level, which uses the "ALARM" function of the DLG, and has been set at 25mm.

When (ii) is activated the power supply will be tripped and the solenoid ramped to zero current.

Both the above trip levels are adjustable. See the Instruction manual.

NOTE that should the DLG lose line voltage, or be switched off, the trips will become inoperative, therefore, the unit should always be switched on.

If the level probe becomes detached the helium level reading will read high - thus disabling the trips. It is therefore important to make sure this does not happen.

See Installation Procedure for connection into the system.

See manual for detailed description of operation.

The DTG200 Digital Temperature Gauge

See also the manual.

This is a six channel instrument which biases and monitors the resistance of the rhodium-iron RDT's installed in the solenoids (RDT = Resistance Dependent Thermometer).

The RDT's are 4 terminal, and all 4 wires are switched to a 25-way 'D' type connector at the back panel. See Fig.5 for wiring.

The DTG converts the resistance of the RDT to a temperature in Kelvin. The front panel meter is auto ranging and gives three significant figures. The unit is accurate to around 1% when monitoring channel 1.

The DTG unit can only be calibrated to one particular sensor characteristic, and so will not read entirely accurately on any other channel.

The degree of error in the DTG reading for each of the thermometers is given in Appendix 'C'.

The list of channels versus sensor positions is given in the 'Thermometers' section of this manual above.

See Installation Procedure for connection into the system.

The DTG unit has no interlocks.

The NLG Nitrogen Level Gauge

See also the manual.

This is an instrument that monitors the level of liquid nitrogen in the liquid nitrogen reservoir in 5 discrete steps.

The unit monitors the resistance of 5 platinum RDT's mounted in the level gauge probe.

See Fig.8 for the NLG pin out.

The 5 levels roughly correspond to :-

20%, 40%, 60%, 80% and 100% Full
100% = 30 litres of liquid nitrogen

These levels are indicated by 5 front panel LED's.

NOTE that the LED's light up when their associated sensor is covered by liquid, except the 20% LED labelled 'LOW WARNING', which is unlit when covered by liquid.

The NLG has an interlock which switches on the lowest level, i.e. when the liquid is below 20% and the 'LOW WARNING' LED is lit.

This interlock only triggers the alarm at the REMOTE stations and does not trip the power supply.

If the probe is unconnected the instrument will cause the interlock to funtion.

If the instrument is switched off, the interlock will function.

NOTE that the front panel of the NLG also carries an LED which indicates if the probe is not connected.

There is an adjustment on the front panel labelled 'REF'. This controls the sensitivity of the inputs to the RDT's. To get the best readings the REF pot should be trimmed so that when the reservoir is full the LED's are just lit, then give a quarter turn towards the lit direction. This adjustment has already been carried out at CRYOGENIC and the gauge should be functional.

There have been two modifications to the NLG unit. These are that the front panel connector is not used, and its function has been taken to the back panel, and an extra back panel connector has been added for the interlock connection.

The Penning 505 High Vacuum Gauge

This is a single range instrument measuring from 10^{-2} to 10^{-7} mbar on a single dial.

For details of operation see 505 manual and CP25EK Gauge Head manual.

CAUTION

- Do not connect or disconnect a gauge head with the power ON. The resulting high voltage spark may damage the control unit. Damage to the head may result if this caution is ignored.
- Do not operate above 10^{-1} mbar for long periods.

The gauge instrument box has a 0-10V recorder output which has been utilised to perform the interlock function.

A control box is mounted on the same panel as the vacuum gauge. This takes the recorder output from the gauge and compares it with a preset reference voltage. This voltage has been adjusted to correspond to 2 x 10^{-4} mbar. When the measured pressure rises above 2 x 10^{-4} mbar, a relay contact is opened, causing the 'poor vacuum' interlock to function, tripping the PS120C-H and sounding the alarm at the REMOTE station.

A circuit diagram of the control box appears in Fig.2.

If it becomes necessary to adjust the reference voltage this should be done by removing the 3.5mm jack plug from the back of the gauge box and applying the desired voltage to the plug (pin = +Ve, shell = -Ve). The multiturn pot accessible through the hole in the top of the control box is then turned so that the relay switches. This can be detected by monitoring the continuity of the relay output connector.

NOTE that if the Penning 505 gauge box is switched off at the front panel, the interlock will not function.

NOTE that if the pressure is greater than 200 mbar, the gauge will read $<10^{-7}$ mbar, thus the interlock will not function (this is probably of little consequence).

NOTE that if the 3.5mm jack is removed, or the line voltage removed from the control box, the interlock will function causing PSU TRIP and ALARM.

Metrolab PT3020 NMR Teslameter

In conjunction with the four miniature probes supplied this unit allows measurement of fields in the range of 0.7 Tesla to 13.7 Tesla.

The supplied probe ranges are :-

Probe No.5	:	0.7 to 2.1 Tesla
Probe No.6	:	1.5 to 3.4 Tesla
Probe No.7	:	3.0 to 6.8 Tesla
Probe No.8	:	6.0 to 13.7 Tesla

CAUTION : probe numbers 6, 7 and 8 contain liquid D_2O samples. Care must be taken not to expose them to temperatures below freezing (probe No.5 contains a solid sample and is, therefore, not affected by this consideration).

The probes are interfaced to the Teslameter via an 8-way multiplexer. The amplifier necessary for operation of the system is incorporated in the multiplexer.

The miniature probes are supplied with integral three meter leads.

A ten metre cable is supplied for multiplexer to main unit connection.

The format of the main unit supplied is NIM 3 width,

Three models of operation are available at the front panel of the main unit : MANUAL, AUTO and SEARCH. These modes are also available via the remote interface plus further options in the SEARCH mode.

In MANUAL mode the output radio frequency of the probe is user adjusted until an NMR signal is detected.

In AUTO mode the radio frequency is automatically adjusted over +/- 5% of a user pre-set frequency until an NMR signal is detected.

In SEARCH mode under LOCAL operation the radio frequency is automatically adjusted over the whole range of a selected probe until an NMR signal is detected.

In SEARCH mode under REMOTE operation there are further possibilities.

- The search may be started at a defined radio frequency.
- The search may be carried out over a number of probes.
- The speed at which the search is performed may be varied.

For full details of Teslameter operation please refer to the manual.

The Junction Panel

This custom built unit provides a convenient junction box for the various LOCAL units and the REMOTE annunciator panel. It organises the various relay outputs from the monitoring instruments to provide a single cable connection to the annunciator panel, and forms part of the interlock interrupt circuit for the PSU.

The LOCAL Emergency Stop button is located in the centre of the junction panel. To enable the PSU to ramp once this button has been pressed the button must be released by turning it clockwise. A general indication of the solenoid status is provided by the illumination of either the "CLEAR" or "TRIPPED" lamps.

The helium trip relay is located in the junction panel.

The back panel of the unit has the following connections :-

"ANNUNCIATOR PANEL"	This 12-way MIL-SPEC plug carries signals to and from the annunciator panel.
"POWER UNIT"	This 6-way MIL-SPEC socket connects the interrupt circuit to the PS120C-H.
"VACUUM"	This 3-way XLR socket connects to the trip relay in the vacuum gauge.
"NITROGEN"	This 4-way XLR socket connects to the trip relay in the NLG.
"HELIUM"	This 5-way XLR socket connects to the DLG210. Two pins connect to the auto-refill relay in the DLG and two pins carry the "ALARM" output from the DLG to the helium trip relay in the junction panel.

NOTE : The interlocks will only operate when the junction panel is powered up. This is done through connection to the annunciator panel. To ensure that the two units are connected together and to the power supply, the interrupt circuit to the power supply from the annunciator panel through the junction panel is, in normal operation, closed. Any break in this circuit will act as a FALSE interlock; the solenoid will be tripped and the PS120C-H rendered inoperative.

Please see Fig.3 for the Junction Panel Circuit Diagram.

WARNING

An attempt to short-circuit the pins on the PSU back panel which connect to the interrupt circuit will, as indicated above, allow operation of the PSU without the protection afforded by the interlocks.

The Remote Computer

Full control of all power supply and Teslameter functions is possible at the computer. A three serial port TANDON PC-X personal computer is supplied for this purpose. The link to each of the two LOCAL units under computer control is via INMAC "clear signal" cable. Data transmission and reception is by line drivers. These plug directly into an instrument's RS232 port and will transmit data at up to 19.2K baud.

40 metres of INMAC cable is supplied for each of the links.

For the commands accepted by the power supply and the Teslameter please see the appropriate manual.

The Remote Annunciator Panel

This is a custom built unit enabling remote monitoring, to a limited extent, of the solenoid and cryostat status.

As already stated, the annunciator panel must be connected to the junction panel for operation of the power supply.

The various interlocks are co-ordinated in the panel. Certain FALSE interlocks open the interrupt circuit relay (located in the panel) which trips the PSU.

The front panel of the unit has the following indicators :-

"NITROGEN TRIP" "HELIUM WARN" "HELIUM TRIP" "VACUUM TRIP"	These four push-to-test lamps indicate the alarm functions - when the nitrogen level is below 20%, the helium level is below 80mm, the helium level is below 25mm, or the vacuum space pressure is above 2×10^{-4} mbar.

All four failures trigger the alarm, but only the latter two trip the PSU (the "NITROGEN TRIP" is simply a warning, despite the labelling).

"SILENCE/RESET" — The above lamps will remain lit until the fault has cleared itself. They will only go out if this button is pressed. Thus, they have a memory of intermittent faults. If the "SILENCE/RESET" button is pushed before the fault is clear the "ALARM SILENT" button will light until the fault clears. In both situations the SILENCE/RESET will silence the audible warning device.

If either of the "EMERGENCY STOP" buttons have been pressed the SILENCE/RESET must be pressed after releasing the "EMERGENCY STOP" button to enable the PSU to ramp.

"POWER" — This indicator is lit when line voltage is present at the back panel. This is NOT an ON/OFF switch.

"ALARM SILENT" — This indicator is lit when a fault is still present once the "SILENCE/RESET" button has been pressed.

"CLEAR" — This indicator is lit when the PSU is enabled to ramp the solenoid.

"TRIP" — This indicator is lit when the PSU has been tripped.

(Only one of the above two lamps is lit at any one time).

"EMERGENCY STOP" — When this button is pushed the solenoid current is ramped down at the maximum rate (-15 Volts). In order to enable the PSU to ramp the button must be released by turning it clockwise.

<u>The audible warning device</u> is mounted in the front panel, and is triggered by any of the four interlocks mentioned above. It can only be turned off with the "SILENCE/RESET" button.

<u>NOTE</u> - if a second interlock trips before another has cleared, the audible warning device will not restart. All faults must be rectified before the audible warning is retriggerable.

The back panel of the annunciator panel has the following connections :-

"POWER"	The 117 Volt line input is plugged in here.
"JUNCTION PANEL"	This 12-way MIL-SPEC socket carries low level signals to and from the junction panel.
"1A FUSE"	Insert 1A 1¼" HRC mains fuse here.

An unmarked 6-way MIL-SPEC socket is also provided. This allows monitoring of the annunciator panel status at other remote stations.

See Fig.5 for pin allocation and Fig.4 for circuit diagram.

See Installation Procedure for connecting into system.

See Appendix 'B' for cable specifications.

The logic of the annunciator panel is all transistorised relay, operating at 12 Volts. This logic gives good noise immunity due to the high threshold voltage and slow response of the relays.

The logic states are :-

12 Volts	= TRUE
0 Volts or O/C	= FALSE

INSTALLATION PROCEDURE

A) Uncrating

The solenoid and its electronics and cables are packed into a single wooden crate with two main compartments.

First, using a crowbar, prise off the top of the crate. The front may then be removed. This is one of the larger panels.

Firstly, remove all the electronics and cables from their compartment and from around the solenoid.

The nails in the solenoid restraining pieces may then be prised out. The restraining pieces will then slide out.

The solenoid may then be pulled forward out of the crate on to a pallet.

Pay special attention to the vacuum valve, vacuum gauge, and other fragile parts which protrude from the top of the solenoid.

NOTE that the solenoid is shipped under vacuum.

A packing list is included in the documentation.

B) Mounting the Instruments

All the instruments except the VAC GAUGE/NLG panel must be mounted on trays. The PS120C-H especially must not be hung from its mounting brackets as it is too heavy.

Space must be left behind the PS120C-H for adequate air cooling. See manual.

C) Mounting the Solenoid

The solenoid may be mounted using the M10 clearance holes in its feet.

NOTE that the solenoid tie rods are good for 250 Kg in any direction. Please take note of any adjacent iron objects when placing the solenoid.

D) Installing The Helium Level Probe

Fit the silicon O-ring, compression ring and knurled collar to the exposed port on the top castle. Push the probe through the port until it sits fully home inside the collar. It should pass down through its guide tube with little resistance.

Our ref: J.2282
TRIUMF

The leads are NOT demountable, When we took the He Can out we found that the leads are soldered at the bottom of the He-can. MG & BH Aug 78

E) The NOT Demountable Current Leads

Remove the stoppers from the current lead ports and insert the demountable current leads. Screw the leads into their sockets using the box spanner provided.

They should screw in and out with little resistance and should stop abruptly on sertion when the coupling cones meet. Do not attempt to force rotation of the leads at any time. This may damage the leads or the connections to the coil.

Whenever the current leads are inserted into the cryostat they must be clean and dry. Water on the mating cones or studding will freeze and will lock the leads into their connectors at the base of the neck, making their removal impossible without warming of the cryostat.

The top castle is stamped at the current lead ports and the protection lead terminals to indicate the internal wiring of the solenoid. See Fig.7 for schematic of coil wiring.

F) The Helium Transfer Syphon

The helium transfer syphon should be inserted down the port in the top plate of the top castle until the PTFE cone on the tip of the syphon mates with the syphon cone coupling at the base of the cryostat neck. Aproximately 53cm of the syphon leg should be clear above the top castle when the syphon is in place. The knurled cap on the port may then be screwed down to lock the syphon and make a gas tight seal.

G) Connecting the Cables

Refer to Appendix 'B' and identify each cable.

CAUTION

Make sure that none of the instruments are switched on before connecting or disconnecting any of the cables. This applies particularly to the vacuum gauge where disconnection in the power-up condition can result in arcing across the output terminals.

1 Connect the two 4 metre power leads (cable No.1) to the brass tops of the removable solenoid current leads using the M6 screws and washers.

Connect the other ends of the power leads to the M8 terminals of the PS120C-H. Always use two 13mm spanners on these terminals to prevent them twisting.

BOTH ENDS OF THE CURRENT LEADS MUST BE VERY SECURELY CONNECTED.

NOTE - when disconnecting the power leads make absolutely sure that there is no current in them. Firstly, the PS120C-H should be ramped to zero current and then switched off. The voltage readout should be zero (a slight positive voltage could indicate that current is still flowing in the thyristors).

Make sure there is much less than 1 Volt across the current terminals by an independent measurements.

FAILURE TO OBSERVE THESE INSTRUCTIONS COULD RESULT IN SERIOUS DAMAGE TO THE EQUIPMENT AND FATAL INJURY TO PERSONNEL.

2 The thermometer cable (cable No.2) should now be connected between the back panel of the DTG and the junction box mounted under the top vacuum can of the cryostat.

The junction box is connected to the thermometers and the N_2 boil off heaters through a pair of cables leading to two 10-pin connectors let into the base of the top vacuum can. The connectors on the junction box and the cryostat are paired. It is important to follow this pairing - 1 goes to 1, and 2 goes to 2.

For pin allocation see Fig.1.

3 Now connect the DLG cable (cable No.4) to the probe and to the instrument.

4 Now connect the NLG cable (cable No.5) to the nitrogen instrumentation/fill castle and to the NLG back panel.

5 The vacuum gauge extension cable (cable No.6) should be connected to the gauge and the instrument box. The ends are polarised. **DO NOT DISCONNECT WHILST POWERED UP.**

6 Connect the gauges to the junction panel using the appropriate cables (cables 9, 10 and 11).

7 Connect the switch heater/voltage sense cable (cable No.3) to the cryostat top castle and the PS120C-H.

8 Connect cable No.7 between the junction panel and the annunciator panel.

9 Connect cable No.8 between the junction panel and the PS120C-H.

10 If a remote computer is being used connect it to the LOCAL units using cables 12 and 13. Connect cable 12 to the PS120C-H, and cable 13 to the Teslameter. (INMAC drivers to PSU, and Modular Technology drivers to the Teslameter - the drivers are configured differently and so are not interchangeable).

11 Connect NMR probes, multiplexer and Teslameter according to the instructions in the manual.

12 Connect the shim coil supply lead (cable No.16) to 10-pin connector 'B' in the top castle.

The line voltage cables may now be fitted with the appropriate connectors and plugged into the instruments.

NOTE that the PS120C-H runs from the 208 Volt supply.

CAUTION

Ensure that the four protection leads (supplied fitted) from the cryostat top castle to the thyristor protection unit are securely connected. If the protection leads are removed or replaced take care not to rotate the current terminals as this could damage the internal leads.

Our ref: J.2282
TRIUMF

EVACUATION PROCEDURE

Before cooldown the vacuum in the cryostats should be better than 10^{-2} mbar.

If the pressure is higher than this a suitable vacuum pump (diffusion or turbo) should be used to bring the pressure down. Although the solenoids were shipped under a good vacuum, this is lost over time due to out gassing.

Always pump the connecting hose down before opening the system vacuum valve.

CAUTION

When releasing the vacuum in the solenoids the vacuum valves must always be opened slowly. If in doubt fit a blanking flange with a 1/8" hole and release through this.

The total release time should be around five minutes.

FAILURE TO OBSERVE THIS INSTRUCTION COULD CAUSE DAMAGE TO THE SOLENOIDS.

Our ref: J.2282
TRIUMF

COOLDOWN PROCEDURE

Approximately 80 litres of liquid nitrogen and 130 litres of liquid helium are needed to cooldown and fill the reservoirs of the solenoids.

During cooldown of the system it is very useful to monitor the cryogen level probes and the temperature sensors so these should be checked for operation. The DLG should be set to 'MAX' reading rate.

Nitrogen Reservoir

This should be cooled and filled first so that the shields are cold by the time helium is put into the system. This may take up to 12 hours. The nitrogen boil off will be high until the shields are cold and the radiation load from the helium reservoir is removed.

NOTE that if the fill rate to the nitrogen reservoir is very fast the NLG may read high.

Nitrogen Precool

With the syphon in the down position liquid nitrogen should be pumped into the solenoid helium space to precool the magnet coil to around 100 Kelvin. The temperature sensor 'A' at the top of the magnet can is the best indiction of the coil temperature during transfer of cryogens.

Once the sensor 'A' indicates that the coil has reached around 100 Kelvin the nitrogen flow should be stopped.

The sensor 'B' may be checked to see if any liquid nitrogen has settled in the bottom of the magnet can. If it reads around 77K then there is liquid present. This may be boiled off using the 40 Watt heaters provided.

Once all nitrogen liquid has been boiled off the neck and magnet can should be flushed with helium gas to remove all traces of nitrogen gas and air; if these gases are present during the helium cooldown they may freeze on the current lead connectors, locking these leads in place.

The heaters are four 20 ohms resistors. A maximum current of 1 Amp should be passed through them.

The heaters are terminated in pairs at the thermometer junction box mounted on the underside of the top vacuum can (jack socket inputs).

When the temperature on sensor 'B' has risen to above 90K the heaters may be switched off. The temperature should not return to 77K. If it does then liquid is still present and the heating should continue.

It is very important that the last trace of liquid nitrogen is removed from the helium space before further cooling.

Our ref: J.2282
TRIUMF

Helium Cooldown and Fill

When the solenoid shield temperature falls below 130 Kelvin (sensor 'F') liquid helium may be transferred into the solenoid. Inevitably this will start with a transfer of relatively warm helium gas as the syphon is cooled. In order to flush all traces of nitrogen gas from the system the first few minutes of the transfer should be done with the syphon in the down position. It may then be lifted until the gas emerging at the solenoid end is colder than the solenoid.

The syphon should always be in the down position when cooling from 100K to 4K.

Sensor 'A' will give a good indication of the magnet coil temperature during cooldown.

When the magnet coil has cooled sufficiently, liquid helium will start to condense in the bottom of the magnet helium jacket. This will be indicated by sensor 'B' reading 4.2K +/- 0.5K.

After a few minutes the DLG will start to indicate that liquid helium is collecting in the reservoir. The reservoir is full when the gauge reads 460mm The rate should be set to 'MAX'.

After helium is indicated in the reservoir, the syphon may be withdrawn to the UP position.

After the reservoir is full the DLG rate should be sent to 'MIN' to minimise the helium boil off.

HELIUM REFILL

The helium reservoir may be refilled, even while the solenoid is at full field, by using the syphon in the UP position. The syphon will be warm so the flow of helium gas down it should be slow until it has cooled down and liquid is emerging into the reservoir. If a large volume of warm gas is injected into the reservoir the existing liquid helium may be blown off and the magnet may quench.

Since the syphon may only be withdrawn about 50mm, it is not worth while refilling the system until the level is below this as the first warm gas will blow off any liquid above this level.

ENERGISATION PROCEDURE

Once the cryostat is filled with cryogens and is connected into the instrumentation, it may be energised.

Energisation from the LOCAL station is described below.

For complete familiarisation with the controls available at the front panel of the PS120C-H the manual must be read.

- Turn on all instruments (and ensure annunciatior panel is connected).
- To reveal the previous power-down status of the PS120C-H press any power supply front panel button (the ZERO selector is convenient as it will have no other effect).
- Set the switch heater voltage. For simple ramping where the settling time of the field is not important, 2 Volts is sufficient to open the switch. However, if it is important to minimise the time constant of the coil and switch circuit at least 5 Volts should be applied to the heater.

  The heater voltage should be kept as low as practicable as this will keep the boil off due to the heater down.
- Set the desired 'MID' and 'MAX' valvus. 73.35 Amps corresponds to a solenoid central field of 7 Tesla. Do not set either of the values higher than 75 Amps. 10 A = 0.9617 T
- The ramp rate may be controlled either by setting the ramp rate parameter to the appropriate value, or by setting the limiting voltage (this controls the ramp rate by limiting the voltage at the power supply terminals).

  Convenient settings for the above are, respectively, 0.06 A/s, or 9.9 Volts. These will cause the solenoid to ramp to full field in approximately 20 minutes.
- Push the 'MID' or 'MAX' button.
- Boil off during ramping of the coil will be high due to heat dissipation in the switch and switch heater (e.g. for 10 Volt ramping 1 Watt will be dissipated in the 100 ohm switch, and with 5 Volts across the 100 ohm switch heater 0.25 Watts will be dissipated, equivalent to a total of 1800cc of helium per hour). A further 1800cc/hour of helium boil off can be expected due to eddy current heating. (This boil off is proportioned to the square of the voltage across the coil).

The current and voltage displayed on the power supply readout will begin to rise. The ramp will be controlled by the set ramp rate until the voltage rises to the limiting voltage, when this value will then determine the time to field.

The various parameters may be adjusted during ramping.

When the solenoid has ramped to the set current the voltage readout will fall to the level of the purely resistive voltage drop down the current levels (around 0.3 Volts for 73 Amps).

If it is desired to put the coil into persistent mode once the PSU has completed ramping, turn off the switch heater, wait for approximately 1 minute to allow the switch to cool and ramp the leads down, following the procedure below. If a large negative voltage is displayed on the PSU, the coil has not gone into persistent mode. In this case stop the ramp down, ramp the coil back up to the desired field (it is not necessary to switch the heater on again if this is done quickly), wait for a longer period,and attempt to ramp the leads down again.

De-energisation, or ramping down, is achieved by pressing the ZERO button on the PS120C-H.

The voltage readout will show a negative inductive voltage, and the current will ramp to zero at a rate determined by the set ramp rate or voltage limit value (whichever is the lower).

Shim Coils

Two sets of shim coils are wound, orthogonal to each other, on the main solenoid to allow final adjustment of the homogeneity of the solenoid. Each set - x or y - consists of four 25 turn saddle coils.

The shim coils may be energised independently using separate low voltage power supplies. They are not fitted with permanent mode switches.

Up to 5 Amps may be used to energise each shim coil set. Current input is via multipin 'B' on the top castle. See Appendix 'D' for pin allocation.

Transferring Control Between Stations

Selection of remote control is by the REMOTE button on the front panel of the PS120C-H. Under normal circumstances ramping must be inactive (at ZERO, MID, MAX or PAUSED) for remote control to be selected.

For full details on transferring control on remote operation of the PSU, refer to the PS120C-H manual.

TROUBLE SHOOTING

No Current When Demanded

- The interlocks may be operating. Check helium level and vacuum level. See Interlock Table. Make good apparent fault.

- The 12 Volt supply to the Interlock or EMERGENCY STOP buttons may be down. Refer to circuit diagrams and check voltages. Replace fuses if necessary.

- One of the cables may have come loose. Check all cables and connectors are secure. Check jack plug in back of vacuum gauge.

- If the voltmeter climbs to 15 Volts and the power supply shuts off, then the current lead circuit is open. Check all current leads and solenoid. These may have failed.

APPENDIX 'A'

INTERLOCK TABLE

Interlock	**Effect**	**Indications** Local	Remote
Helium level less than 80mm	Alarm at REMOTE station	DLG readout + "RELAY" light off	Audible warning + "HELIUM WARN" lit
Helium level less than 25mm	Trip PS120C-H + alarm at REMOTE station	DLG readout. Current ramping down or zero	Audible warning + "HELIUM TRIP" lit
Nitrogen level less than 20%	Alarm at REMOTE station	"LOW WARNING" lit on NLG	Audible warning + "NITROGEN TRIP" lit
Vacuum bad, greater than 2×10^{-4} mbar	Trip PS120C-H + alarm at REMOTE station	VAC gauge readout. Current ramping down or zero	Audible warning + "VACUUM TRIP" lit

Our ref: J.2282
TRIUMF

APPENDIX 'B'

CABLE SPECIFICATIONS

1) Cable Identification Table

Cable No.	Length	Connectors	Description	No. Off
1	4m	M8 crimp, M6 crimp	Solenoid current lead	2
2	4m	25-way 'D' type M, 25-way 'D' type F	Thermometers	1
3	4m	10-pin F, 5-pin DIN M	Switch heater/ voltage sense	1
4	4m	7-pin M, 7-pin F	DLG probe	1
5	4m	10-pin F, 10-pin M	NLG probe	1
6	5m	BNC M, BNC F	Vac gauge ext.	1
7	40m	12-way MIL-SPEC F, 12-way MIL-SPEC M	Junction panel - remote annunciator panel	1
8	2m	9-way 'D' type M, 6-way MIL-SPEC M	Junction panel - PS120C-H	1
9	2m	8-way ring-lok F, 5-pin XCON M	DLG - junction panel	1
10	2m	4-pin XCON F, 4-pin XCON M	NLG - junction panel	1
11	2m	3-pin XCON M, 3-pin XCON F	Vacuum gauge relay box - junction panel	1
12	40m	RS232, RS232 INMAC line drivers	INMAC cable PS120C-H - remote computer	1
13	40m	RS232, RS232 Modular Technology line drivers	INMAC cable Teslameter - remote computer	1
14	1m	M6 crimp, M8 crimp	Protection leads	4
15	600mm	10-pin F, 10-pin M	Thermometers - junction box	2
16	4m	10-pin F, 3 x 4mm jack plugs	Shim coil supply lead	1

APPENDIX 'C'

DTG200 READOUT COMPENSATION

The DTG is calibrated to sensor 'A'. To obtain correct temperature values from readouts on the other channels compensation must be made for the varying resistances of the other thermometers. On channels 'B' to 'F' the DTG reads high by the percentages given below, relative to the readout.

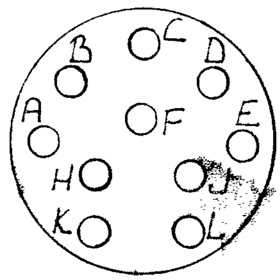
DTG channel	% Error
(1	
2	0.00)
3	0.45
4	1.87
5	4.82
6	8.36
	10.18

For example :- A reading of 81.8K on channel 4 (N_2 reservoir) indicates a real temperature of 77.8K.

Our ref: J.2282
TRIUMF

APPENDIX 'D'

TOP CASTLE MULTIPIN CONNECTIONS



Pin layout (pin view)

Port 'A' : Superconducting switch heater plus voltage sense.

Pin	Connection to
A	~~Switch heater (+ve)~~
B	~~Switch heater (-ve)~~
− C	~~Voltage sense (tap No.1)~~) See FIGURE 4
+ D	~~Voltage sense (tap No.4)~~)

Port 'B' : Shim coils

Pin	Connection to
A	x - shim
B	x - shim
C	Common
D	y - shim
E	y - chim
F	Common

A & B are shorted on top
C & F —//—
D & E —//—

Disconnected Jan 93 BH

	Top	in He can
AE	254 Ω	
CE	130 Ω	126.5
AC	130 Ω	122.0

Brass tube common 0.125 inch OD
—//— x-shim } 0.090 inch OD
—//— y-shim } —//—

Shim coils disconnected from the He Dewar to reduce heat load.

Our ref: J.2282
TRIUMF

APPENDIX 'E'

NOTES ON USE OF LINE DRIVERS WITH THE PS120C-H POWER SUPPLIES

The PS120C-H has been successfully tested with 50m of INMAC "Clear Signal" cable and 8125 series line drivers.

It should be noted that the male and female versions of the line driver (8125-E and 8125-F, respectively) differ only in respect of the sex of the connector and as a result of this only the female version (8125-F) is correctly configured to RS232 standard.

Furthermore, the male version is not universally suitable for connection to DCE equipment because pins 20 & 6 and 4 & 5 are linked. For these reasons the following modifications have been made to the male version (8125-E) to enable it to be plugged directly into the PS120C-H.

1) Interchange tracks to pins 2 and 3
2) Cut track to pin 4 (floats high on PS120C-H)
3) Cut track to pin 20 (floats high on PS120C-H)

It is also very important to correctly connect the 4 wire signal cable if the data link is to function.

Connect as below :-

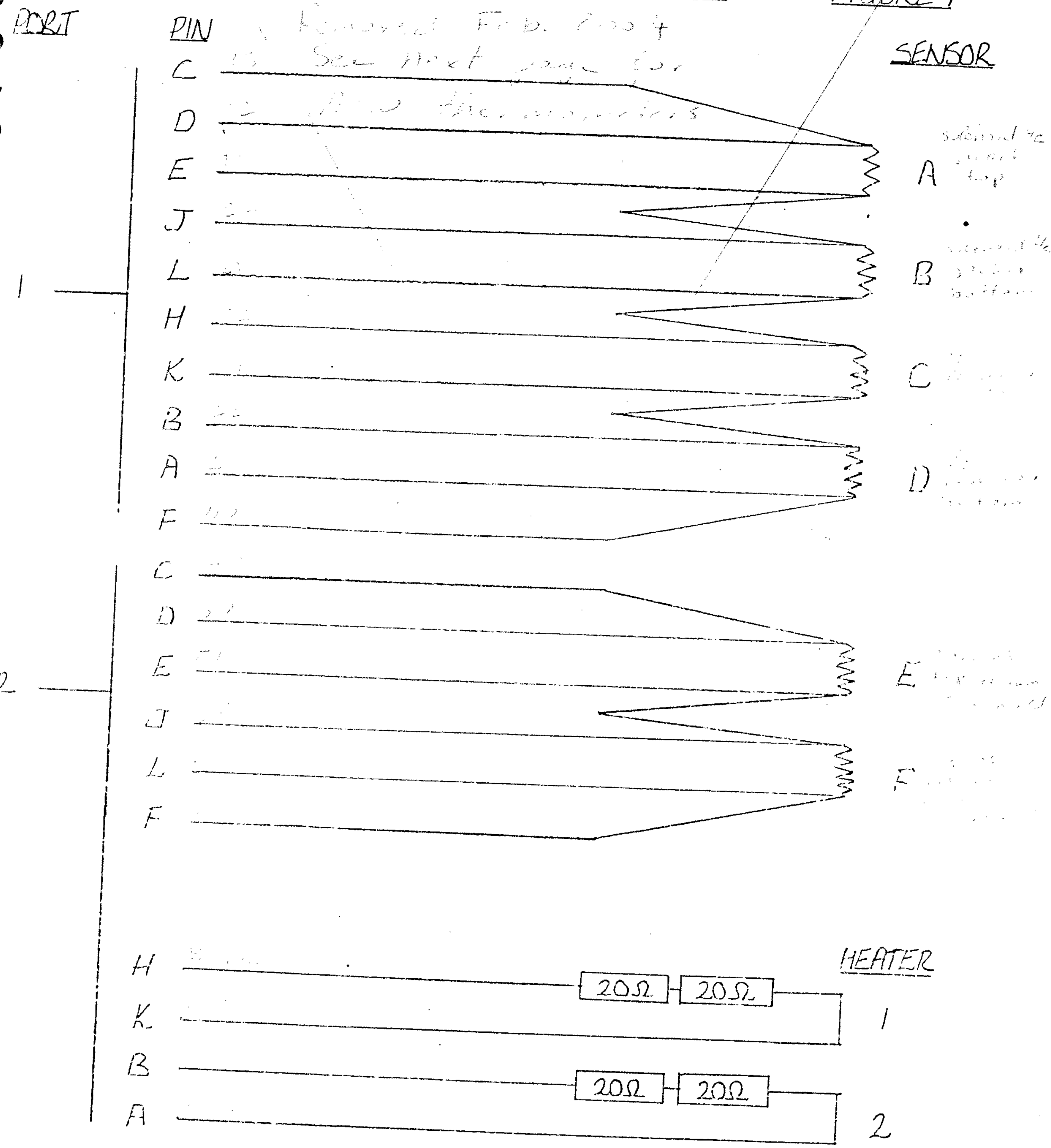
8125-E pin	Colour	8125-F pin
T+	Brown	R+
T-	Green	R-
R+	White	T+
R-	Yellow	T-

→ D

Solenoid
Shell
Top

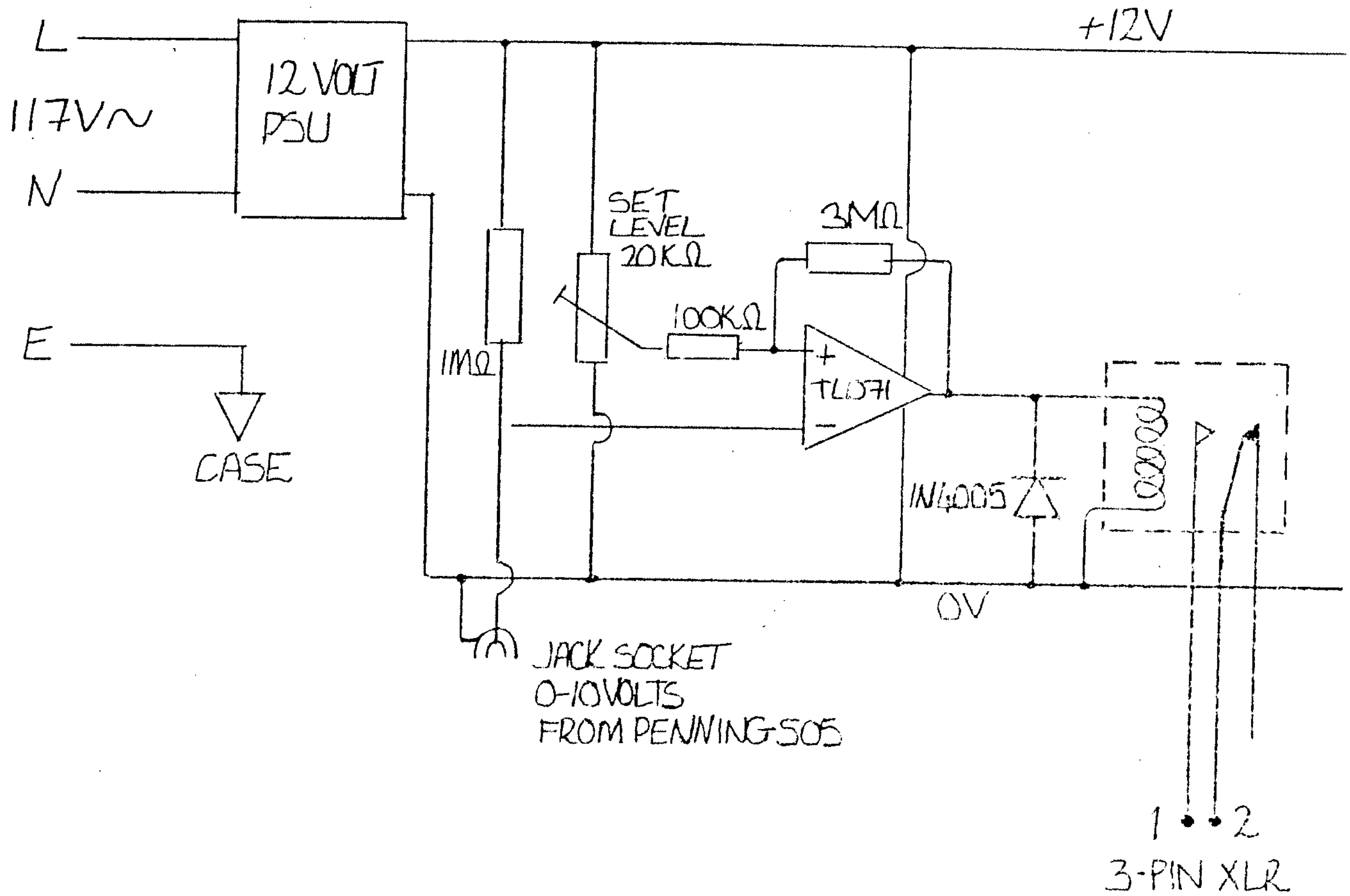
THERMOMETER AND HEATER CIRCUITS

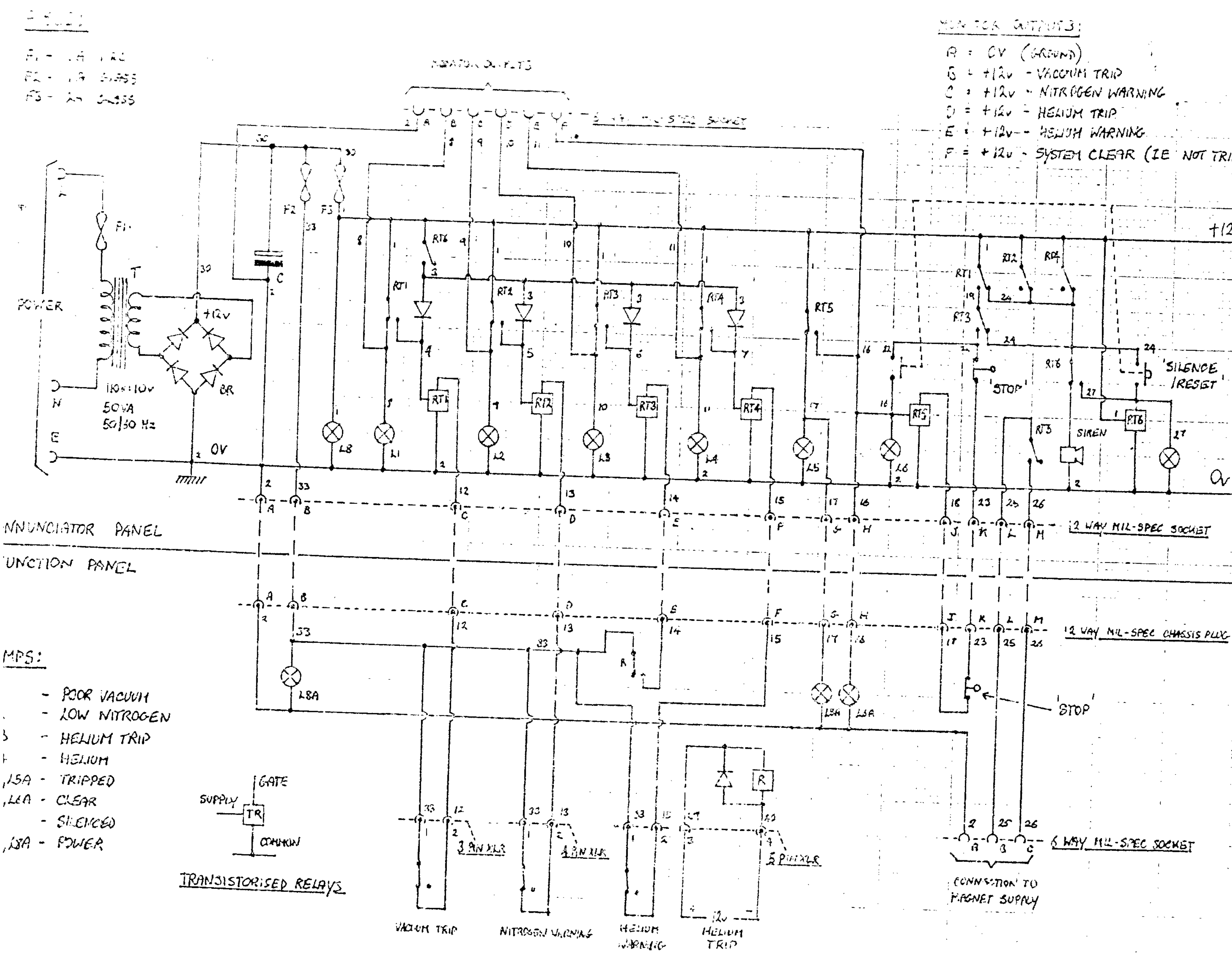
FIGURE 1



VACUUM GAUGE RELAY BOX CIRCUIT

FIGURE 2

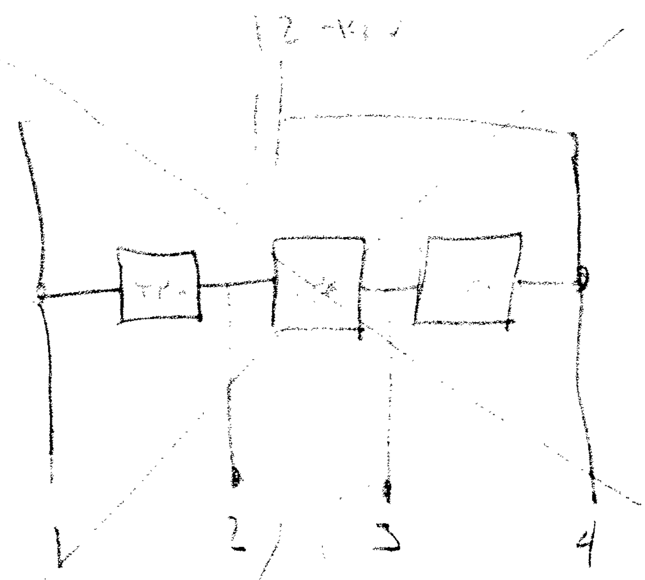




JUNCTION PANEL / ANNUNCIATOR PANEL

FIGURE 3

Thyristor check



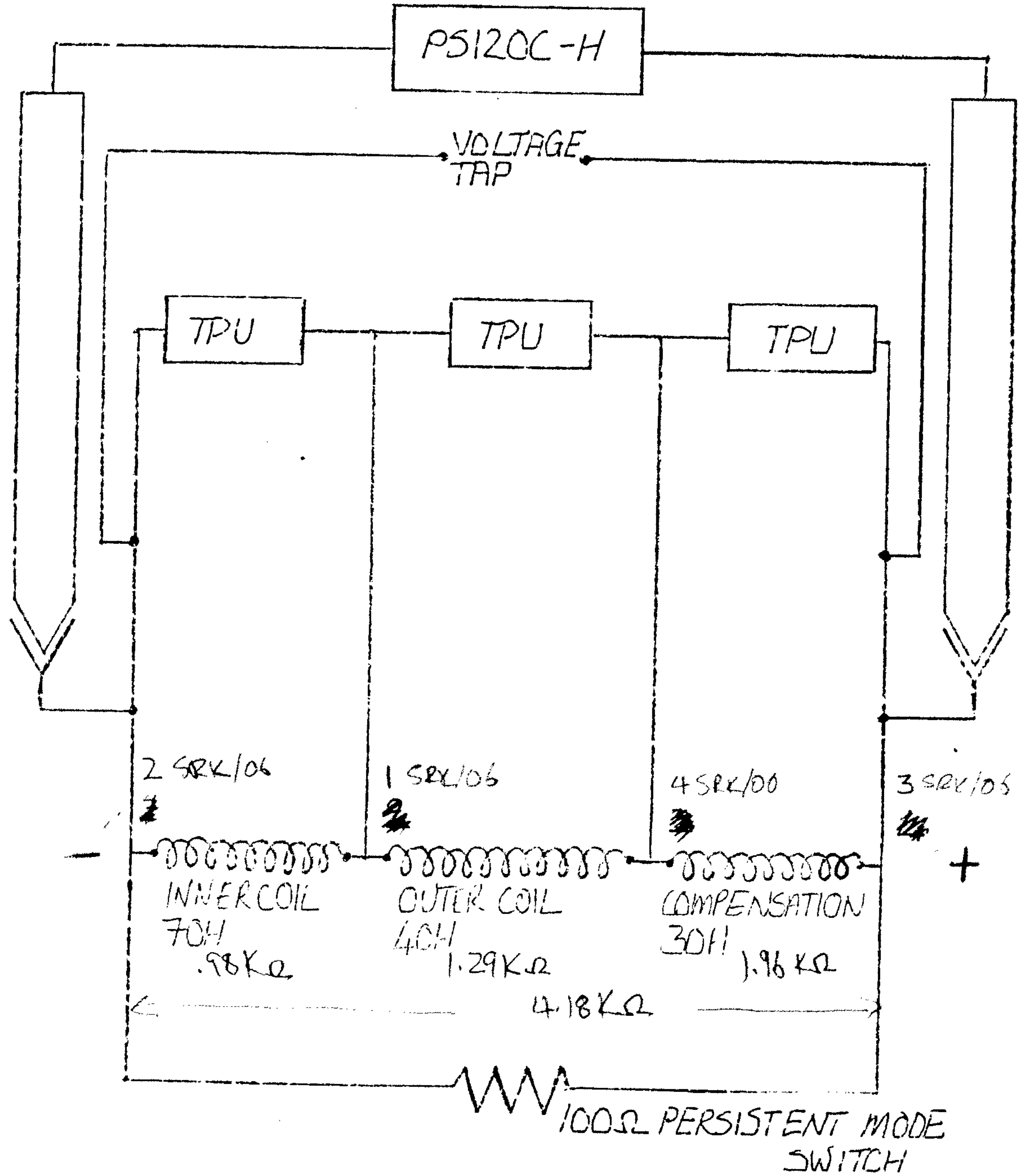
12 V { New connection shown in Fig 4 3/1/06

~~2-3 @ 12V.~~

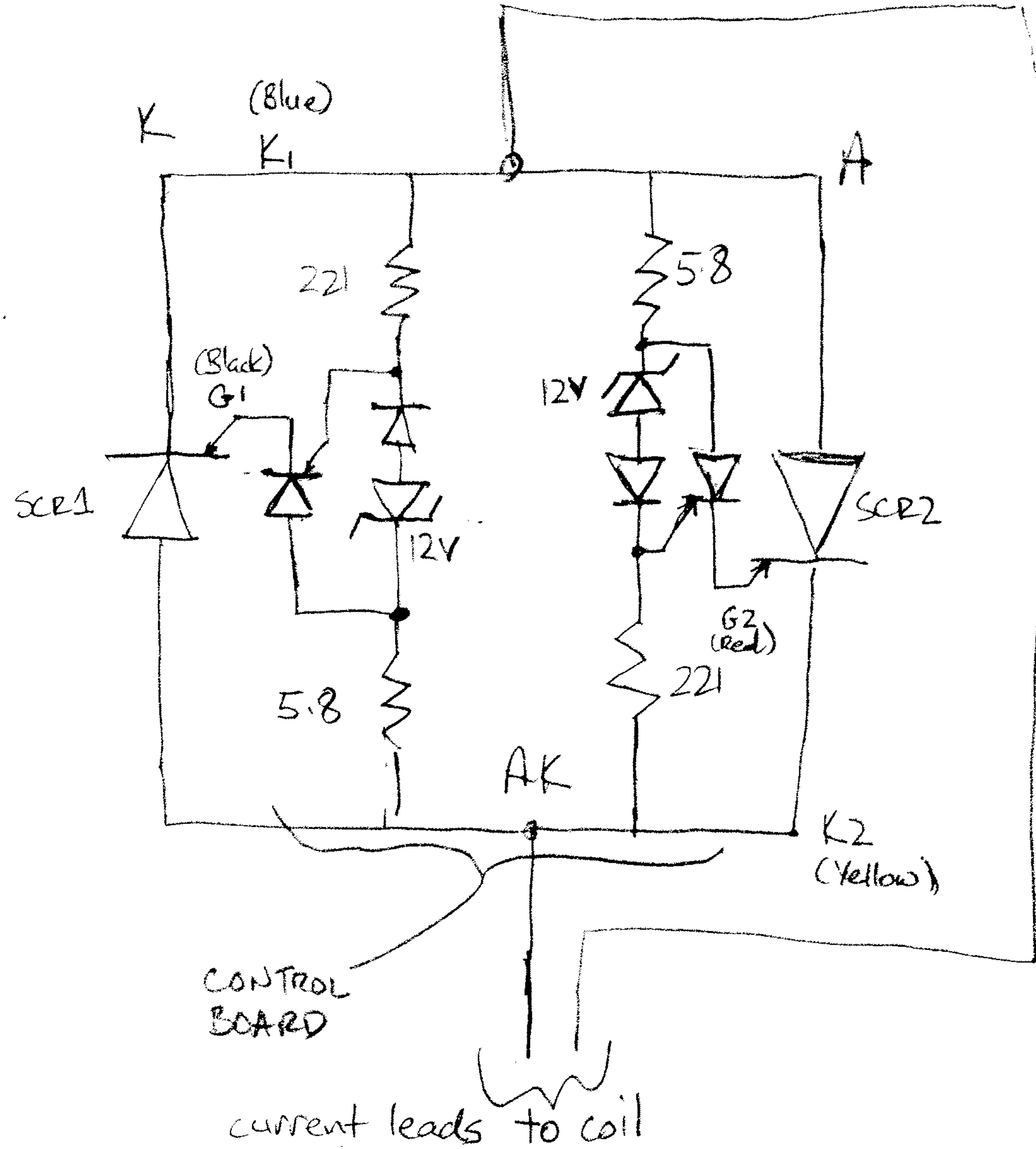
~~1-4 @ 30 nothing shorted~~

CRYOGENIC

MAIN COIL WIRING FIGURE 4



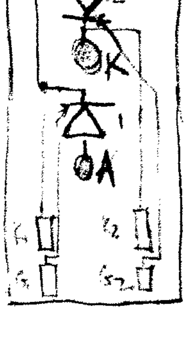
TPU - THYRISTOR PROTECTION UNIT



TPU UNIT (BIPOLAR using DUAL CENTRE TAPPED SCR's BELOW + CONTROL BOARD)

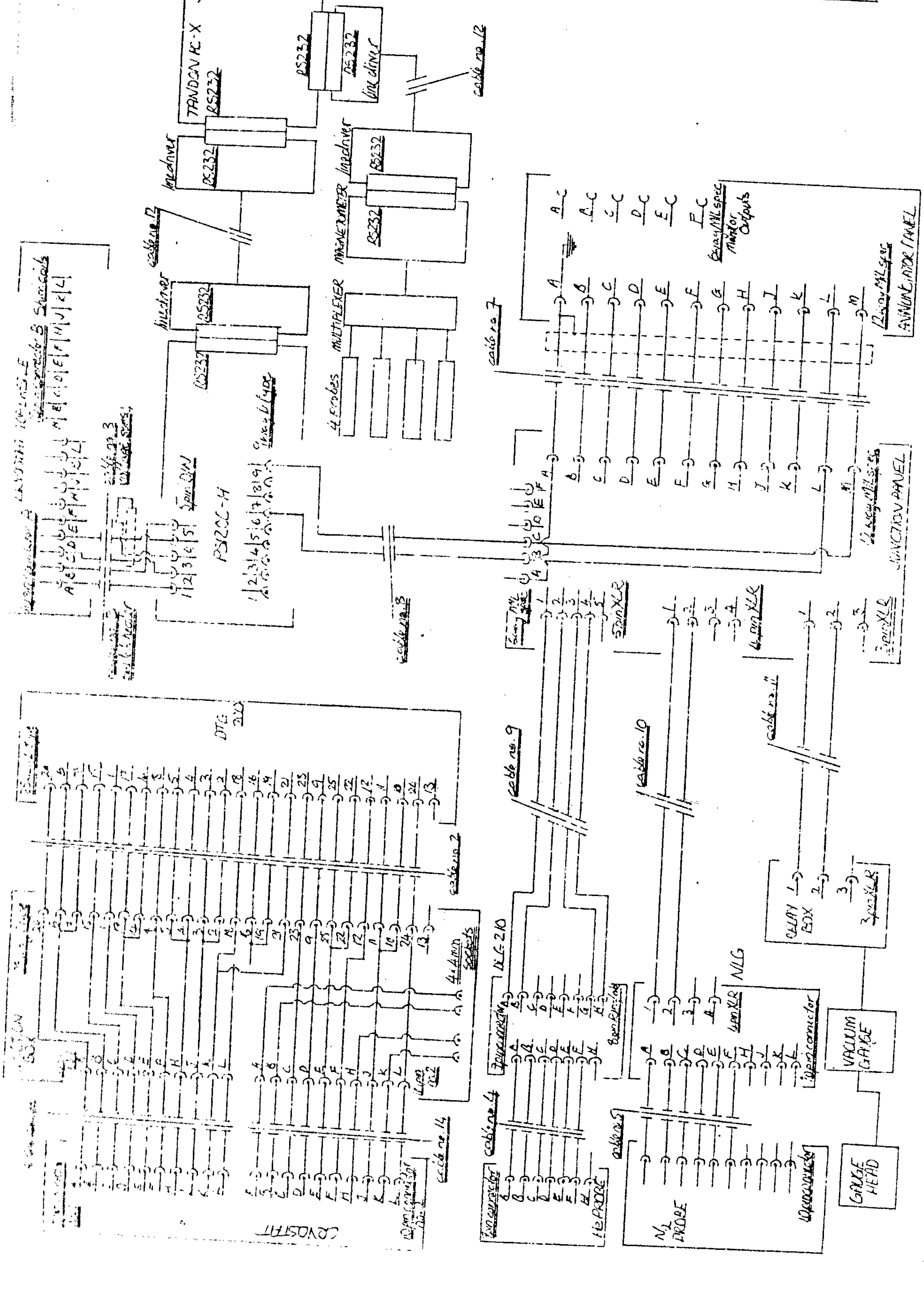
(SRK 05/2006)

DUAL CENTRE TAPPED SCR



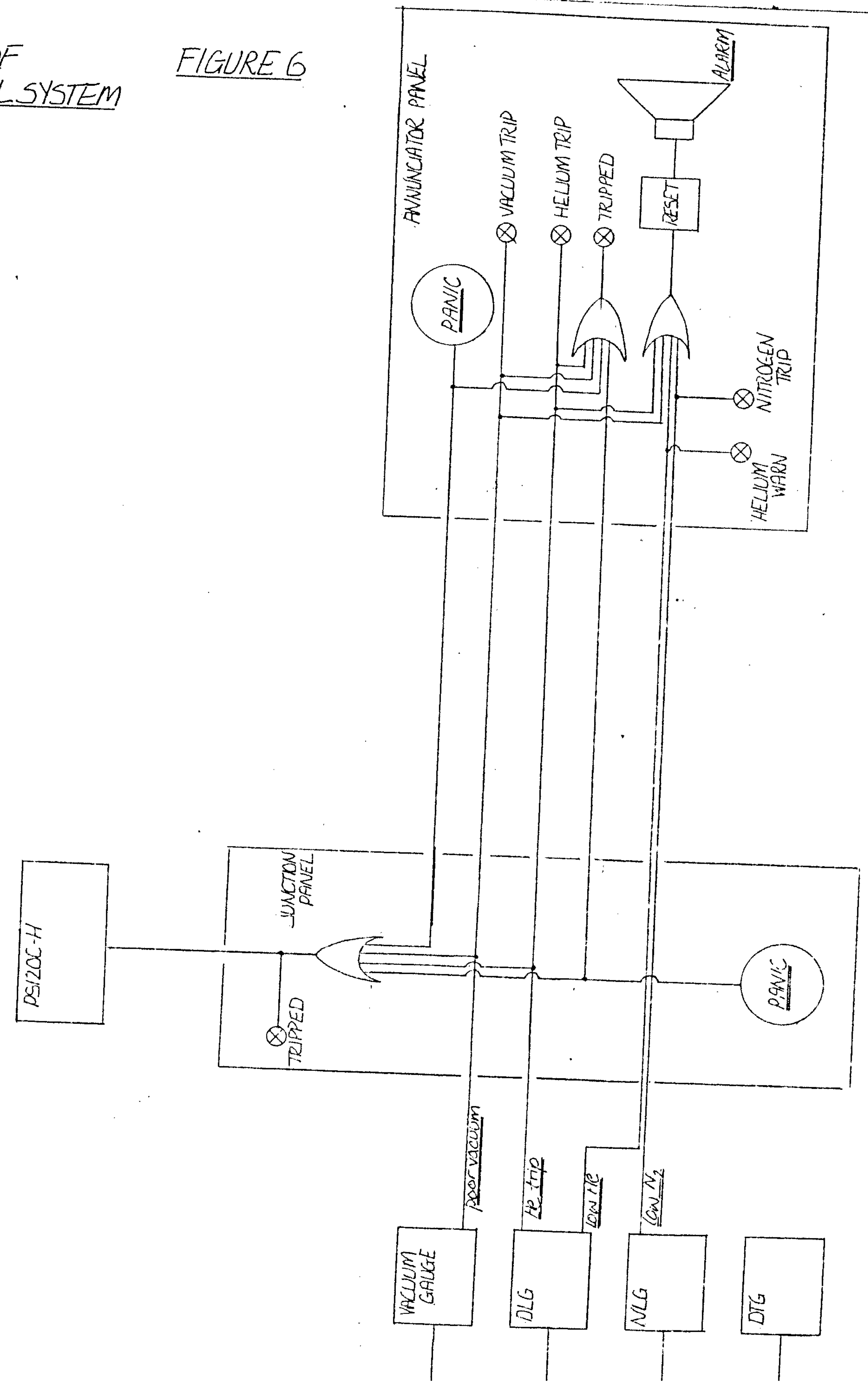
CRYOGENIC

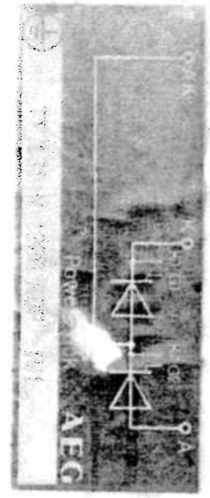
PIN CONNECTIONS FIGURE 5

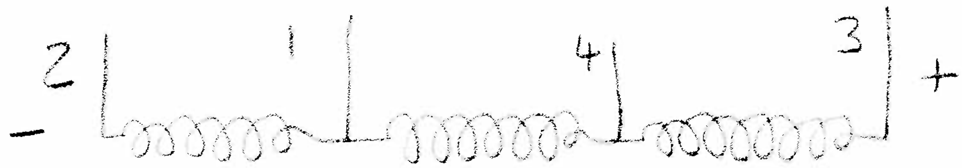


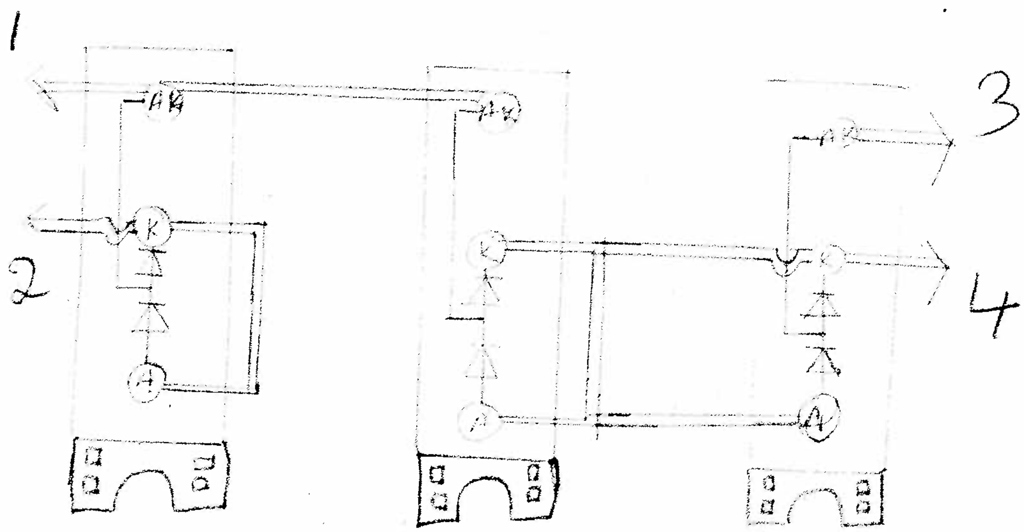
CHEMATIC OF CONTROL SYSTEM

FIGURE 6









TPU electronics

voltage across 1-2 fires @ ± 12V
" 1-4 "
" 3-4 "

CRYOGENIC

THYRISTOR CABLING

FIGURE 7

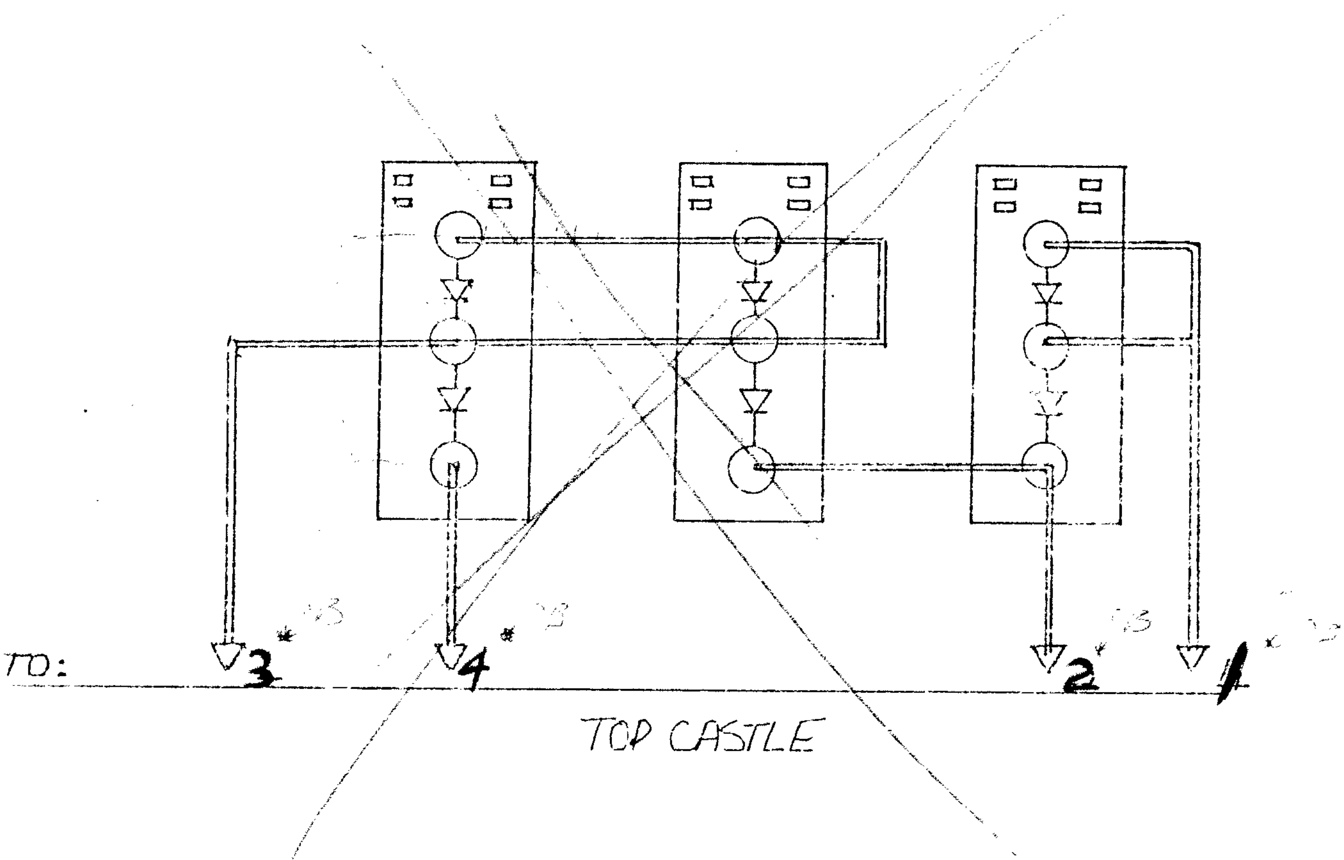


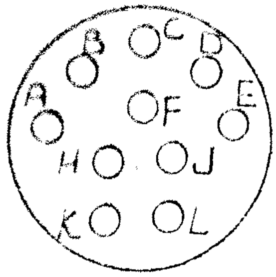
Diagram is not correct!
Wire according to numbers on cable and numbers punched on top of magnet

* Numbers in black are correct 11/13/91

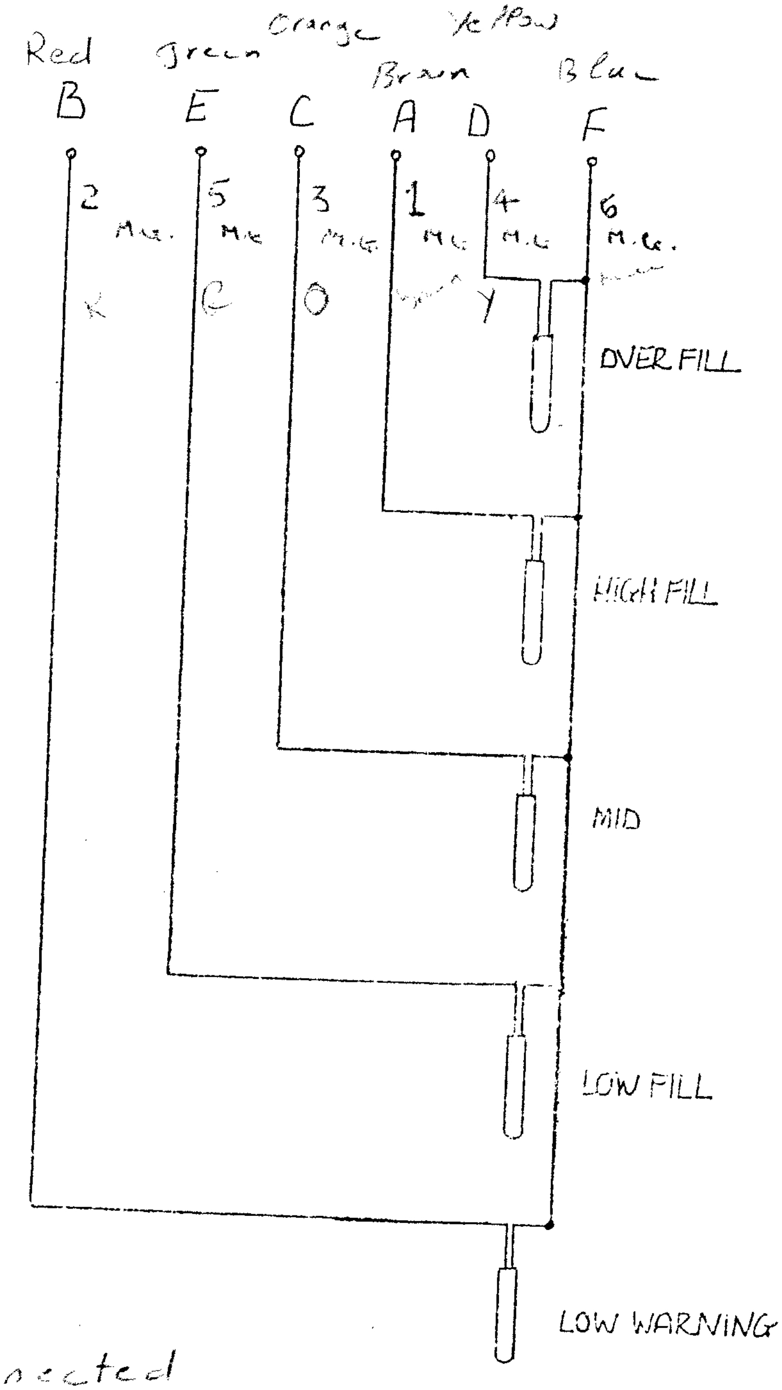
CRYOGENIC

NLG PROBE PIN OUT

FIGURE 8



PROBE PIN OUT



5 OFF PLATINUM SENSORS

100Ω at 273K

19Ω at ~~19K~~ 77°K

M.G.

Black	L	Not Connected
white	K	
grey	J	
purple	H	

March 2003 BH

SHIM COIL WINDINGS

FIGURE 9

ONE SHIM COIL SET SHOWN (FOUR, 25 TURN SADDLE COILS).

SECOND SET IDENTICAL, BUT WOUND AT 90° TO THOSE SHOWN.

COILS SYMMETRICAL ABOUT MAIN COIL CENTRE.