OPERATING MANUAL FOR
CLEO II
SUPERCONDUCTING MAGNET

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CLEO II MANUAL

Section 1 describes the main aspects of operating the magnet.

Sections 2 to 8 describe the important details of each sub-system.

Section 10 concerns routine maintenance checks and advice on assembly/disassembly, plus documentation.

CONTENTS

6 COIL POSITIONING SYSTEM

7 INSTRUMENTATION AND CONTROL

8 VACUUM SYSTEM

10 ROUTINE MAINTENANCE, ASSEMBLY, DISASSEMBLY AND DOCUMENTATION

NOVEMBER 1987 Issue 1

MAIN PARAMETERS FOR CLEO II MAGNET

MAGNETIC FIELD	1.5 T
CLEAR BORE	2.9 m
AXIAL LENGTH	3.8 m
CURRENT	3250 A
COIL INDUCTANCE	4.6 H
CONDUCTOR	Niobium Titanium/Copper composite embedded in high purity aluminium.
QUENCH PROTECTION	Self protecting via close-coupled secondary.
COOLING SYSTEM	Liquid helium from storage dewar located above magnet using natural (thermo-syphon) circulation.
INSULATION SYSTEM	High vacuum, liquid nitrogen cooled radiation shield, superinsulation.
TOTAL MAGNET WEIGHT	20 Tonnes
TOTAL YOKE WEIGHT	970 Tonnes

1 OPERATING THE MAGNET

1.1 Cooldown

There are certain preliminary checks to be made before the cooldown routine can be started. Those which concern the refrigerator, liquid nitrogen supply, the operation of the vacuum pumping system and power supplies and control systems are seen as being outside the scope of this manual; others which relate directly to the magnet are listed below:

a) The initial rate of pumpdown of the vacuum system should be limited to no more than 300 mbar per hour, to avoid disturbance to the superinsulation. This is best achieved by throttling on the rough vacuum backing line.

b) The power supply for the magnet must be inspected visibly to ensure all connections are properly made and the discharge (or protection) resistor is connected across the coil terminals.

c) All instrumentation and control circuits must be connected, verified and trip and alarm functions in operation.

d) The two adsorption pumps (sorbs) on the coil assembly should be out-gassed at up to 100°C and at a vacuum level of better than 10^{-3} mbar for a period of about 6 hours.

e) The vacuum level in the cryostat as measured by the gauge heads in the current lead stack control cabinet (CLSCC) must have been better than 10^{-3} mbar for a period of 36 hours or more.

f) All the axial supports which are used to position the coil within the cryostat are secured and the loads as indicated by the 20 load sensors on the radial and axial coil supports are within the expected limits. The two lower axial supports (X and W) should then be relieved of load as described in section 6.5; other procedures for an initial cooldown are mentioned in section 6.5.1.

The cooldown process for the helium system must be controlled by the helium refrigerator so as to avoid excessive pressure in the dewar or excessive differential temperatures in the coil. These limits are defined in section

7.5 of this manual.

The radiation screen is cooled using clean, liquid nitrogen and the temperature and flow rate are controlled by the cryogenic mixer unit described in section 3.2. The recommended pressure and flow rates are given in section 3.3.

The cooldown of the helium system and of the radition screen should be started simultaneously and with the pre-set ramp rate of the screen, a temperature of 80K should be reached in 180 to 220 hours. During the early stage of cooldown say from 300K to 150K, a significant proportion of the screen cooling is via radiation to the (colder) coil assembly and in this time any hold-up on cooling the coil will be reflected in a delay in cooling the radiation screen.

During cooldown, the loads in the coil supports should be monitored and appropriate action taken if needed. Temperature differentials should also be monitored and action taken if any lack of uniformity is indicated.

When the coil has reached a temperature of about 60K, the sorbs should be heated to drive off any adsorbed gases etc. Details are given in section 8.3.2.

The radiation screen cooldown is automatically controlled and when the base temperature is reached control is transferred to the steady-state controller. When this condition has been reached, the programme keyswitch should be opened to prevent inadvertant or unauthorised ramp-up initiation (section 3.4).

As the coil assembly reaches a temperature of 4.5K, liquid helium will accumulate in the dewar. When the dewar is over ¼ full, the helium flow circuit can be changed over from the cooldown mode to the steady state mode. This causes the input helium to be discharged at a high level into the helium dewar and the feed to the coil to be taken from a low level ie, below the liquid surface. In this mode helium should continue to accumulate in the dewar and the thermosyphon system circulate by natural convection.

When the coil is at 4.5K, the gas flow in the current leads should be checked in the current lead stack control cabinet (CLSCC) via the two rotameters. With the two servo-controlled valves shut manually, the flow should be set via the two bleed valves to give a reading of 20 l/min for each lead. With the servovalves in automatic mode, the flow up each lead at zero current should be 43 l/min, time-averaged. At the same time, the helium dewar neck cooling gas should be checked: there are four necks in the dewar (one central, three for the valves) and all are counter-flow cooled. The flow adjusting valves should be set so that each flow leaves the neck at about 3° to 5°C below ambient temperature.

When the coil is at temperature, the radial and axial supports must be re-secured as detailed in sections 6.5 and 6.5.1/6.5.2.

1.2 Energising of Magnet

Although the power supplies and their control do not form part of this contract, it is essential that a careful check is made of the electrical connections to the magnet and in particular between the magnet and any protection resistor connected across the coil terminals. It is also important that the magnet current is not allowed to exceed the specified rating of ~~3266A~~. 3500

As the magnet is protected by a passive secondary winding, additional losses are produced during charging: the nominal charge time is 2 hours. A linear charge (uniform rate of change of current) will produce a loss of 7.5 watts. A flat-top charge can be used if it is related to the current being passed so that as the magnet reaches the full rating, the rate of charge reduces: two such recommended procedures are given below:

a) Linear charge:

Current : nil to 3266A
Voltage : 1.5V
Charge time : 165 mins
Loss : 7.5W

b) Flat-top charge:

Current	:	0-2800A	2800-3266A
Voltage	:	2.2V	1.5V
Loss	:	15W	7.5W
Charge time	:	100 mins	20 mins
Total charge time	:	120 mins	

As the current in the magnet increases, the gas flow control will automatically allow more gas to pass up the lead, so as to maintain the set point temperature. At full current 3266A, the gas flow should be approximately 66 l/min for each lead.

If the coil position has been adjusted since the last time the coil was energised, the magnetic forces on the coil need to be monitored and any increase in the indicated loads guarded against. In all supports, tension loads are positive, compression loads are negative and whilst the axial forces are unstable (force acts in the direction of the coil's displacement) the radial forces are expected to be stable. The following guides therefore apply as the current is increased:

i) Increasing tensile axial force - the coil should be moved towards the axial support (or services) end of the magnet - see section 6.6.1.

ii) Increasing compressiveaxial force - the coil should be moved away from the axial support (or services) end of the magnet - see section 6.6.1.

iii) Increasing net radial force - the coil should be moved in a direction indicated to decrease the load in the supports, and the opposing supports tightened - see section 6.6.2 and following.

iv) Decreasing net radial force - the coil should be moved in a direction indicated to increase the load in the supports, and the corresponding supports slackened - see section 6.6.2 and following.

1.3 Normal Service

When the magnet is at full current, all operations should be monitored by Cornell's control system and provided all parameters stay within their trip or alarm limits, there is no specific action needed. However, it is good practice to check visually that there is no frosting of any of the cryogenic parts, that the flow indicators on the current lead cooling gas are operating correctly and that the loads on the coil supports are not changing significantly.

1.4 De-energising Magnet

1.4.1 Normal shut-down

When the current in the magnet needs to be reduced to zero for operational reasons, a reverse voltage must be applied of a similar magnitude to the charging voltage. This can be provided either by an in-line resistor which is switched into circuit or by the busbar and internal resistance of the power source. Some increase in the helium boil off will be produced due to eddy currents in the secondary winding but this should not cause a problem.

1.4.2 Rapid de-energising of magnet

If it is necessary to reduce the current rapidly, this is possibly by opening the circuit breaker(s) in the leads supplying the magnet. This of course can only be done if there is a resistor permanently connected across the magnet and which is capable of absorbing the full stored energy of the magnet (22 MJ). This action will produce a moderate voltage across the coil leads and to limit this to 160V, the resistor must be no greater than 50 milli ohms. With this resistance in circuit, the coil current will decay with a time constant of 90 seconds, or less, depending on whether the coil has become resistive in this process.

If the coil is rapidly de-energised because a quench has been detected, there will be a considerable boil off of liquid helium and to reduce the load on the helium recovery system, it is suggested that the cryogenic valves in the dewar should be put into the 'cooldown mode' and the refrigerator output reduced to a minimum level. By this means, the thermosyphon system will be cut off and the flow through the coil will be reduced to say 1 gm/sec. The valves are then in the correct mode for a re-cooling of the coil as and when the refrigerator is able to do so.

Wherever the magnet is rapidly de-energised there will be a considerable increase in the boil off of helium and it is recommended that this can be restricted by the operation of the 3 Battig valves in the helium dewar. These valves should be put in the 'cooldown' mode using the pneumatic actuators and then returned progressively into the 'steady state' mode either manually or by electrical operation of the pneumatic toggle valve.

1.5 Warm-up

The procedure on warm up is that the coil and the radscreen should be warmed up at a similar rate without exceeding the specified temperature differentials on either the coil or the radscreen. It is assumed that the coil can be warmed up by circulating gas through it from the refrigerator, with the expansion machines running at low or zero output. The radiation shield cooling system is set to ramp up the temperature of the feed gas at a prescribed rate as outlined in section 3.2.

The actions to be taken are:

a) Release the two lower axial supports, X and W.

b) Put the pneumatically operated cryogenic valves into the 'cooldown' mode so as to circulate helium gas through the coil cooling circuit.

c) Maintain the vacuum system in operation in order to remove as far as possible any contaminants in the vacuum space. When a vacuum level of better than 10^{-4}* mbar has been reached on the pump side of the gate valve, the gate valve may be opened.

(*: This value applies only to the warm-up sequence. In all other cases a vacuum which is better than the system pressure must be reached <u>before</u> the gate valve is opened).

d) Commence warming the coil at about 35 to 40K per day by circulating helium gas at a temperature no greater than 35 to 40K above the coil temperature.

e) Set the ramp up procedure for the radscreen into operation; this is pre-set for a corresponding rate of 1.5K/hour.

f) The helium gas which is returned at ambient temperature from the leads and neck cooling is regulated automatically and should need no adjustment.

g) There should be no need to adjust the radial supports for the coil as during the warm-up they will tend to reduce their tension, but it would be best to monitor the loads during warm-up.

h) Monitor the pressure in the vacuum space during the later stages of warm up and when the coil is above 250K, air-up the vacuum space using dry nitrogen via the special orifice (1.5 mm dia) adjacent to the air admittance valve. It is very important to restrict the air-up process in this way to avoid displacing any superinsulation. Using this orifice, the air-up time is about 12 hours.

i) Ensure that all components in the cryostat are at a temperature of above 10°C before releasing vacuum to atmosphere, if that is necessary. Normal cryogenic practice would be to keep the cryostat under vacuum at all times, unless access is needed to the internals.

2 COIL ASSEMBLY

2.1 Description

The coil assembly comprises a 2-layer superconducting coil which is wound inside its supporting, 40 mm thick, aluminium alloy shell. The conductor is a Nb-Ti/Copper composite embedded in a high purity aluminium matrix to give a conductor section of 16 x 5 mm. The whole assembly is epoxy impregnated and between the coil and the shell there is a 1.5 mm thick aluminium liner of very high purity aluminium to form a secondary winding for protection purposes. With this design the coil is self-protecting in the event of a quench.

The linear current density (A/m) is nominally 1.2 MA/m so as to produce a uniform central field of 1.5T with the iron yoke. At each end of the coil there is an axial length of 887 mm over which the current density is 4% higher than in the central region, so as to improve the homogeneity of the field.

The main parameters of the coil are as follows:

Rated current at 1.2 MA/m mean density		3266 A
Inductance		4.60 H
Number of turns		1281
Axial length	warm	3490 mm
	cold	3475 mm
Mean radius	warm	1540 mm
	cold	1533 mm

At each end of the coil there is a flux loop comprising 20 turns of enamelled copper wire and at the mid plane there is a 6 turn heater wire (constantan) with a rating of 400W continously and 800W for short term use (10 seconds rating). The resistance value is ≈ 100 ohms and for continuous rating 200V, 2A d.c. should be used.

2.2 Protection

The coil is self-protecting so that if a quench is caused, it will spread rapidly through the coil and the current will decay safely without any external action being needed. In this case most or all of the stored energy will be deposited in the coil assembly.

As additional protection, a resistor can be connected across the coil permanently (at ambient temperature) and if a quench is detected, the current supplying the coil is interrupted by a d.c. circuit breaker. This causes the coil current to decay on a timescale defined approximately by the ratio of (coil inductance/resistor value) and the majority of the energy is dumped in the room temperature resistor. The peak voltage across the coil will be 160V with a 0.05 ohm dump resistor. The resistor should be centre-tapped to earth via an earth current sensing leakage resistor so as to minimise the voltage to earth as seen by the coil.

In the self-protecting case and the active - protected case the following parameters apply for a quench from full rated current:

	Self Protected	Active Protected
Decay time (seconds)	52	52
Peak voltage across coil (V)	0	160
Peak resistive voltage within coil (V)	350	110
Maximum temperature in coil (K)	82	65
Stored energy dissipated in coil	100%	44%

Although it is not essential, it is recommended that if an active quench system is provided, the valves in the helium dewar supplying the coil should be changed from the steady state mode to the cooldown mode.

This action will restrict the flow of helium to the coil and thus restrict the boil-off gas so as to allow the refrigerator system to absorb the gas with a minimum loss of helium to the recovery system.

A gradual reversion to normal service mode can be made manually so that the amount of helium gas which is produced can be regulated to suit the capacity of the refrigerator system.

3 RADIATION SCREEN

3.1 Description

The radiation screen assembly comprises two cylinders, an inner and an outer, joined at each end by a number of aluminium plates and supported by 16 radial ties connected between the outer radiation screen and the ambient temperature jacks attached to the outer vacuum casing. This ensures that when the coil radial supports are adjusted, the radiation screen moves with the coil, within the vacuum casing. The aluminium cooling pipe, through which nitrogen flows, follows a serpentine pattern through the inner screen, starting and finishing near TDC, before crossing over to the outer where it follows a similar pattern before exiting via the neck. Cooling of the radiation screen is by conduction from the screen to the pipework and thence to the temperature controlled flow of nitrogen coolant. The space between the radscreen and the vacuum casing is filled with a multilayer wrapping of NRC-2 (aluminised mylar).

Each radiation screen cylinder is assembled from 8 curved aluminium honeycomb panels bonded and rivetted together. Each panel is made from two sheets of aluminium alloy, sandwiching an aluminium alloy honeycomb and the cooling pipe.

The stainless steel pipes carrying the nitrogen to and from the radiation screen are attached to the radiation screens in the neck and the service turret. They emerge via cryogenic bayonets from the top of the service turret alongside the current leads; the flow pipe is the one closest to the helium dewar. The transition between the stainless steel pipe in the neck (chosen for ease of welding) and the aluminium pipe in the screen (selected to minimise problems of differential thermal contraction) is made at the level of the O.V.C neck flange. The main dimensions of the radiation screens are as follows:

		293 K	77 K
Radial thickness of screen	=	15.4 mm	
Outer radius of outer radiation screen	=	1690 mm	1683 mm
Inner radius of inner radiation screen	=	1485 mm	1479 mm
Axial length of screen	=	3630 mm	3616 mm

3.2 Cryogenic Mixer Unit

The cryogenic mixer unit is designed to cool the radiation screen from ambient to approximately the temperature of liquid nitrogen and then to regulate the flow of liquid nitrogen to match the heat load on the screen. During the cooldown a pressure of 25 psig is required to maintain a constant flow of gaseous nitrogen through the mixer turbulator (4g/s at no less than 25°C). A controlled flow of liquid nitrogen (0 - 4g/s) is mixed with the gas in the mixer/turbulator to provide a high velocity flow of gaseous nitrogen at the desired temperature to cool the screen. In steady state operation the liquid nitrogen flow is controlled to produce a fine mist of high velocity coolant.

The mixer unit comprises two assemblies as follows:

(a) Electronic Temperature Controller

This is mounted in the magnet control case. The temperature controller consists of two industrial process controllers, the GULTON 2050 and 2072, with associated control relays, pneumatics and interlocks. Refer to A S Scientific drawing A1/10836 for a schematic of the control circuit. The 2050 controller is programmed to regulate the liquid nitrogen flow during cooldown to achieve the desired ramp rate. Throughout the cooldown process the 2072 acts only as a differential alarm monitor ensuring that excessive temperature gradients are not produced. In steady state operation the 2050 is disabled and control of the LN_2 flow is transferred to the 2072. Two resistance temperature sensors, one a duplex (RT1), attached to the pipe feeding nitrogen from the mixer/turbulator to the radiation screen, the other (RT2), attached to the return pipe at the bottom of the current lead stack, are the process variables for cooldown and steady state operation. A further duplex temperature sensor (AST1a) is attached to the nitrogen feed pipe within the vacuum space at the base of the current leads. This provides the option of controlling the coolant flow based on the temperature of the flow into the radiation screen rather than into the transfer line. Certain functions are protected by keyswitches because inadvertent excessive cooling could cause damage to the radiation screen.

Visual indication is provided of the following:

(1) Control circuit live (incorporates lamp test switch).

(2) Gas block valve open SV1

(3) Liquid block valve open SV2

(4) Liquid/gas cooling.

(5) Liquid cooling.

(6) Alarm B (red)

(7) Alarm A (amber)

(8) Mains failure. Permissible period exceeded

(9) Nitrogen gas supply pressure (PG1).

(10) Nitrogen liquid supply pressure (PG2).

(11) Pneumatic control supply pressure (PG3).

(12) Liquid nitrogen control valve pressure (PG4).

Control switches on the front panel are:

(i) Programme lock - keyswitch - used to lock 2050 out of control loop to prevent unauthorised ramp up initiation - close to start - should be opened once cooldown is completed.

(ii) Programme hold - latching pushbutton - used to hold programme at any point - open to hold, close to restart - must be closed before programme can start.

(iii) Key and press mains failure - keyswitch used to reset controller after mains failure period exceeded.

(iv) Open/close valves - latching pushbutton - used to open/close both block valves. If open for period longer than that set for mains period drop out then to close valve will require closure of "Mains failure. Permissible period exceeded ....." keyswitch.

(v) Programme ramp-up - momentary pushbutton - used to switch from steady state operation to the "warm screen ramp". Operational only when 2072 is controlling and must be depressed for a period of more than 1 minute. Programme lock switch and hold switch must be closed before this will work.

(vi) Auto/manual switch - keyswitch to changeover control of

LN_2 valve.

(vii) Manual LN_2 valve control - dial control of LN_2 valve opening.

(viii) Lamp test - momentary pushbutton - close to test.

Relay contact indication of the alarm conditions is available in the control case (de energised open-alarm condition - ~~de~~energised closed-safe condition). The lockable front panel prevents unauthorised adjustment of set point or use of abort facility and should always be kept closed. Adjustment of the control parameters for both controllers should not be attempted without reference to Oxford Instruments. ?

(b) Mixer/Turbulator Unit

This should be located near to the supply of liquid nitrogen. The unit contains the following:

(i) A vacuum insulated mixer/turbulator chamber.
(ii) Gas and liquid block valves.
(iii) Gas regulator.
(iv) Liquid nitrogen control valve.
(v) Pressure relief valve between liquid valves
(vi) Gas entry
(vii) Liquid entry and exit via cryogenic bayonets

3.3 Cooldown

The Gulton 2050 has a programmed ramp facility set to take the radiation screens, as represented by RT1, from ambient to 77K and is used to control the pneumatically operated LN_2 valve through a current to pressure transducer. The screen inlet temperature is progressively reduced in accordance with the set-ramp rate but deviation of the inlet temperature from either the ramp set point by more than ± 15 K (Alarm B), as sensed by the 2050, or from the screen outlet temperature by more than 40 K (Alarm A), as sensed by the 2072, will cause the programme to hold until the deviation falls within limits. The alarm conditions will usually be indicated by "Alarm A" or "Alarm B" flashing and electrically by the contact ~~closure~~ of the respective alarm relay. The ramp will then continue

opening

from the holding point. During cooldown the radiation screen temperatures should be monitored for excess differential temperature by the data logger - see section 7.1. After ensuring that the pressure regulator on the mixer turbulator unit has been adjusted for 25 psig and the system has stabilised at the Initial Set Point, the cooldown is started by closing the programme hold button. Refer to Figure 3.1 for the controller flow diagram.

On completion of the ramp down, control is transferred automatically to the 2072 and the following will occur:

(a) The gas block valve will close.
(b) The input to the current to pressure convertor transfers to the 2072.
(c) The setpoint for the 2072 is transferred from the output of the RT1 sensor convertor to the internally stored set point of ~~-187°C~~. 192.5°C
(d) Change of Alarm A function: Deviation of the process variable from the setpoint on the 2050 of ~~20°C~~. 80°C

(e) Change of Alarm B function to:

    (1) Deviation of the input temperature from the final set point on the 2072 of ~~15°C~~.
    (2) Deviation of the process variable from the set point on the 2050 of 20°C.

The programme keyswitch should then be opened to prevent unauthorised ramp up initiation.

3.4 Steady State

The LN_2 flow through the screens is now controlled by the 2072 using the exhaust temperature sensor (RT2) as the process variable. "Alarm A" (indicating a high exhaust temperature) will produce both flashing visual indication and contact ~~closure~~ opening in the case. "Alarm B" (indicating that either an excessive exhaust temperature or that the inlet temperature is high will cause flashing visual indication, contact ~~closure~~ opening and closure of the liquid nitrogen valve. Control is transferred from the 2072 to the 2050 for screen warm up by releasing the keyed switch "Programme hold" and by holding the panel mounted switch 'ramp up' closed for a period of at least 1 minute.

The procedure needed to cope with an extended mains failure period of several hours is not particularly straightforward as it involves re-programming one of the controllers and restoring it on the resumption of supply. Oxford recommend that an un-interruptable supply should be provided for the *controller unit as the power requirements are no more than 300 VA. However, the procedure detailed below in paragraphs 4a) to 4j) is provided in case such back-up power supplie*~~s~~ *are not made available.*

A mains failure period of greater than 16 minutes will cause the time controlled relay to open; reset is only possible by use of the keyed switch. After a mains failure of greater than 4 hours the radiation screen will have risen in temperature so that resetting the controller will cause the introduction of liquid nitrogen to a 'warm' screen. As such the following procedure should be strictly adhered to. The sections and pages referred to in the following paragraphs are in the Gulton 2050 manual.

(1) Check the radscreen temperatures via data logger. If all temperatures are less than 110 K then proceed from (2). If any temperature is more than 110 K then proceed from (4).

(2) If all screen temperatures are less than 110 K, apply 120 Vac power to the electronic unit supply terminals and close the "Press to resume after mains failure" with keyswitch. The 2072 will then introduce liquid to the screens in order to bring the screen temperatures back to the steady state operating point.

(3) Switch back over to normal electrical supply when this is resumed.

(4) If any temperature is more than 110 K then the following procedure should be followed.

(4)a Connect 120V ac supply to the electronic unit supply terminals.

(4)b Switch gas and liquid block valves shut using pushswitch.

(4)c Unlock panel covering front of controllers.

(4)d Ensure that programme is unlocked using keyswitch and press programme hold

(4)e Refer to GULTON 2050 manual and abort programme by holding in RUN/HOLD pushbutton for several seconds - see page 3-22 Section 2.2.12.

(4)f Reprogramme a new set point (ISP) to a temperature that will minimise thermal gradients following the instructions given in section 2.1.3 page 3 - 5. Do not alter any of the other parameters shown in table on page 3 - 6.

(4)g Leave DWELL 1 as set.

(4)h Leave stages 2, 3 and 4 as set.

(4)i Before commencing screen cooldown the mixer/turbulator should be pre-cooled by disconnecting it from the transfer line to the system and opening both the block valves. The programme will be held due to the front panel switch being open and this will allow the mixer/turbulator to cool. Then remake the connection, taking care not to damage the 'O' ring seal, and allow the controller to stabilise the radscreen at the held set point. Check radscreen temperatures during this period before closing the programme switch and allowing the controller to move onto the ramp down.

(4)j Once the 2050 has completed DWELL 1 and has reached DWELL 2 control will pass automatically to the 2072. At this point the 2050 should be reprogrammed for the original Initial Set Point (ISP) of 20°C. The programme keyswitch should then be closed. Transfer back to normal supply once this is resumed.

3.5 Ratings and Protection

3.5.1 Radiation Screen

Steady state

Liquid pressure (minimum) = 25 psia (10 psig)
(maximum) = 40 psia (25 psig)

Nominal flow rate 1.1g/s 90% liquid 10% gas mass fraction

Heat Load = 440 W (specification value) 200-250 W (typical value)

Cooldown

Liquid pressure (minimum) = 40 psia (25 psig)
(maximum) = 60 psia (45 psig)

Gas pressure: same as liquid pressure
Liquid Flow rate = 0 - 4g/s
Gas Flow rate = 4g/s

3.5.2 Mixer/Turbulator

Input pressures for steady state and cooldown for the liquid and gas supplies are as above.

Minimum temperature of nitrogen gas = 5°C
Maximum temperature of nitrogen gas = 20°C
Quality of liquid nitrogen supply better than 95% by mass
Pneumatic dry air supply pressure (minimum) 25 psig
Nitrogen gas pressure regulator setting 25 psig

3.5.3 Mixer Control Unit

Power requirements 110V ac, 50-60 Hz, 300 VA.
Fuse rating = 5 A

Gulton 2050 cooldown controller settings

Starting temperature set point (ISP) = 20°C. See Figure 3.1 and Page 3-11 section 2.2 of the 2050 manual.

Program	Status	Rate °C/hr	Target Temp ~~(K)~~ °C	Time HRS:MIN	Event
RAMP	1	~~1.5~~ 1·0	~~-180.0~~ -70·0	-	0
DWELL	1	-	-	~~10:00~~ 0:0	0
RAMP	2	~~0~~ 1·6	~~-186.0~~ -192·5	-	0
DWELL	2	-	-	~~00:01~~ 15:00:00	0
RAMP	3	1.6	~~25.0~~ -192·5	-	0
DWELL	3	-	-	~~10:00~~ 0:01:00	~~0~~ 1
RAMP	4	~~0~~ 1·6	25.0	-	0
DWELL	4	-	-	~~00:00~~ 48:00	0

Number of cycles = 1

2050 Controller Parameters (see page 3-6)

Parameter		Value		
ISP		~~20°C~~ ?	5°C	
PWR%		~~100~~	-	not available prior to commissioning on site
LOCK CODE		~~9999~~	?	
PB%	~~2·4~~		6.1	
RST	~~2·06~~		3:40	
RATE	~~1~~		0:50	
SPMX	40		40	
PMX%	100		100	
~~CTH~~ ALM 1	15		15	

Alarm 1 - Page 3-7 - set to ± 15K

Gulton 2072 Steady State Settings

Parameter	Value	Section
LOCK	9999 not available	4.7.1
CTH	prior to	4.7.2
CTC	commissioning	4.7.2
PMX%	100% on site	4.7.3
SPMX	30·0°C	4.7.4
SPMN	-200·0°C	4.7.4
RSMX	205°C	4.7.6
RSMN	-200°C	4.7.6
PB%	~~20%~~ 5%	4.7.7
RST	~~20:00 min~~ 40 min	4.7.7
RATE	0	4.7.7
LSP	-192·5	4.7.7
IRT%	75%	4.7.9
ALARM 1	35°C	4.7.10
ALARM 2	30°C	4.7.10

4 HELIUM SYSTEM

4.1 Description

The coil is maintained at its operating temperature by the evaporation of liquid helium. The helium circulates around the magnet by a thermosyphon action from a storage dewar on top of the iron yoke. The working pressure of the system is 1.1 to 1.2 bar absolute which gives an operating temperature between 4.3 and 4.~~4~~6K.

The current leads in the service turret alongside the dewar are countercooled by gas collected in the dewar and the cold end of the leads are held at liquid helium temperature by a reservoir of liquid which is replenished by a second thermosyphon system.

The dewar is insulated by floating radiation screens and requires countercooling up the main neck tube for these to be effective.

The liquid helium is supplied to the dewar and the cold gas is collected from the dewar by the Kabelmetal transfer line. The gas used to countercool the current leads and the dewar neck is returned by an ambient temperature line.

The cooldown of the magnet requires a flow of gas through the cooling pipes on the coil. Since the nature of a thermosyphon circuit requires an open feed and return pipe into the dewar there are 3 pneumatically operated cryogenic valves which operate in two modes:

> Cooldown - where the feed pipe of the transfer line is connected directly to the feed pipe of the thermosyphon system.
>
> Steady state operation - where the helium is fed into the dewar at a high level and the thermosyphon feed pipe is open at a low level in the dewar.

4.2 Helium Dewar & Valves

The helium dewar can store 700 litres of liquid helium which gives an endurance for the magnet of about 36 hours. There are five pipes within the dewar which feed helium to the main system as follows:

- Coil thermosyphon feed
- Coil thermosyphon return
- Current lead pot thermosyphon feed
- Current lead pot thermosyphon return
- Current lead gas supply.

This last pipe collects helium gas at a high level in the dewar and ensures that the gas is at the liquid temperature by allowing heat transfer along a length of pipe which is attached to the circumference of the helium bath below the liquid level before passing through the tunnel to the current leads.

There are no filters on the pipes and so it is important that the helium supplied to the dewar is not contaminated with particles which could affect the cooling system.

The three pneumatically operated Battig valves divert the flow of helium for either cooldown of the coil or steady state operation of the thermosyphon system. The pneumatic system is operated using an air pressure of 5 psi. It should be noted that this is a lower pressure than the maximum stamped on the valve (0.6 bar). The colour coding of the air lines feeding the valves is: blue for cooldown mode, green for steady state (normal service). Further details are shown in Figure 4.1 and on Drawing AJE 0152 and AJE 0151. The pneumatic actuators are double acting and the valve function is as follows:

Valve closed - Port A and B are connected, C is closed.
Valve open - Port A, B and C are connected.

Hence the valve positions are as follows:

Cooldown

Valve	Mode	Port		
		C	A	B
VI Z	Closed	Closed	Connected	
VI Y	Open	Connected		Blanked off
VI X	Closed	Closed	Connected	

Steady State

<table>
<tr><th>Valve</th><th>Mode</th><th>Port
C</th><th>
A</th><th>
B</th></tr>
<tr><td>VI Z</td><td>Open</td><td>Open at a high level</td><td colspan="2">Connected</td></tr>
<tr><td>VI Y</td><td>Closed</td><td></td><td>Closed</td><td>Blanked off</td></tr>
<tr><td>VI X</td><td>Open</td><td>Open at a low level</td><td colspan="2">Connected</td></tr>
</table>

(With the actuator in the up position the valve is open).

Having taken suitable precautions to depressurise the helium system the valve stems can be removed with helium still in the dewar. The seals can then be inspected and replaced according to the manufacturer's instructions:

Alfred Battig AG
CH-8400 Winterthur
Warstrasse 133
Switzerland

Telephone : (0) 52 252769 Telex : 76617

NB - If the stems are removed for more than a few minutes, then stopping off the valve necks and allowing pressure to build up will continue the countercooling on the current leads and the dewar neck.

Within the dewar, on the centreline of the main neck, the coil thermosyphon feed pipe terminates in a stainless steel nozzle. The gas tight connection to the Kabelmetal transfer line is made by a non-metallic bush which will slide over the nozzle and, as the incoming gas cools, it will contract onto the nozzle.

Fitting and removal of the transfer line can only take place when the non-metallic joint is at ambient temperature. Furthermore extreme care must be taken making this connection to prevent damage to the interior of the dewar and the transfer line.

Countercooling of the main neck tube relies on the transfer line being in position which will ensure efficient heat transfer from the neck tube to the counter cooling gas. The three neck tubes for the Battig valves are also countercooled and the gas for all four tubes is collected in a 'ring main' and then sent back to the recovery system. The volume flow rate of gas to provide efficient cooling of the dewar is 7 l/min at STP and the valves on the exhaust of each neck should be adjusted until the temperatures of the neck tubes are identical to within 1°C and the required gas flow is achieved.

- 15 CFH
= 36 [illegible]

4.3 Thermosyphon System

The cooling of the coil uses a thermosyphon system which is supplied from the helium storage dewar. There are two pipes, nominally 16 mm bore, between the coil and the dewar. The feed pipe (downgoing) is isolated from any significant heat source and feeds the bottom of the coil shell. The return (upcoming) pipe is of similar diameter and absorbs heat from the current leads (if any) and from the 70K radiation shield in the neck assembly.

Any heating in the coil is absorbed by 32 cooling pipes which are in parallel and run around the coil from bottom dead centre to top. There are axially aligned manifolds at bottom and top dead centre to connect the 32 cooling pipes to the feed and return pipes. Using this system, all 4K heat loads are absorbed by rising pipes and the resulting difference in fluid density causes a circulation of helium. In the storage dewar the helium gas rises to the free liquid surface and is returned to the refrigerator at 4K; the entry of the feed pipe and the exit of the return pipe are placed at a low level in the dewar so as to be submerged at all times.

There is no active control on this system as it is self-regulating and the mass flow circulating around the system is typically 10 to 15 grams/sec over a wide range of heat loads. In normal service it does no harm to provide a high mass flow, well in excess of the nominal 1 gram/sec which would be needed to absorb 20 Watts at 4K. However during a quench condition, it is preferable to limit the mass flow to a value which does not affect the propogation of the quench eg 15 g/sec or 300 Watt dissipation. This can be readily arranged by providing over-capacity in terms of pipe sizes and then, during commissioning, restricting the flow around the thermosyphon loop by a manual adjustment of a limit stop on the cryogenic valve which is at the entry to the thermosyphon. This is the valve labelled "X" in the helium dewar. During works tests this valve was set up to give an opening of ~~2~~ 1 division~~s~~ on the scale, which corresponds to ? 25 ~~50%~~ opening. The maximum opening (4 divisions) corresponds to a 9 mm stroke.

The whole thermosyphon system vents freely into the helium dewar and so, apart from transient pressures produced during a quench, there is no need to take any particular action during an unscheduled warm up of the coil as there are no trapped volumes which could generate excessive pressure during warm-up. The same applies to the helium pipework in the dewar between valves X, Y and Z; there are no trapped volumes to cause excessive pressure on warm up and the maximum steady pressure in the system is defined by the helium supply pressure from the refrigerator.

5 CURRENT LEADS

5.1 Description

(Refer to Figure 5.1)

3300

The magnet is continuously energised at 3250 Amps and the current leads, which carry this current between ambient and liquid helium temperature, make up about 40% of the heat load on the 4 K system. The leads are therefore designed with the two criteria of efficient useage of cryogens and safety.

The current leads are comprised of six parallel copper rods (which are the conductor) with 111 copper fins. The fins provide a large area for heat exchange to the cooling gas and also increase the thermal mass to dampen the response to any temperature transients in the leads. The gas to countercool the leads is collected in the helium dewar and is fed to the bottom of each lead.

The cold end of each lead is held at the operating temperature of the system by liquid helium which circulates into the helium pot at the base of the leads by a thermosyphon action from the dewar. (This thermosyphon circuit is independent to the coil thermosyphon circuit.) The liquid helium is prevented from leaking up the leads by a PTFE gasket which acts as a seal. Only a nominal leak tightness is required from atmosphere to the current leads and to the helium pot.

The ceramic feedthroughs at the bottom of each lead provide electrical isolation of the conductor to the vacuum casing whilst providing a leak tight joint. The ceramic to metal joint cannot withstand large temperature differences and so caution must be exercised at all times to ensure that the leads are never exposed to rapid temperature changes during cooldown and warm-up.

There are rhodium iron temperature sensors on the gas feed line and the helium pot thermosyphon return pipe. These sensors are monitored by the Doric Data logger section 7.1. Potential tappings are provided so that the potential drop on the leads can be recorded (refer to section 7.4).

The current-feed clamps at the warm end of the leads should be coated with petroleum jelly. Since they are a tight fit on the warm end terminations, M6 jacking screws are provided to push the jaws apart to ease fitting and removal. Although the copper blocks have thread inserts care should be taken not to damage the clamps.

The braids, which provide a small degree of freedom for both movement and alignment between the bus bars and the current lead terminations are rated at 2000 Amps for continuous operation in still air: the increased ohmic heating due to operation at 3250 Amps conveniently offsets some of the heater power which is required to maintain the warm end of the current leads above the dew point.

For all busbar connections the clamping force is important to obtain a low resistance joint. To maintain a sufficient force, disc springs are stacked in parallel pairs against stainless steel load bearing plates. The M8 nuts should be tightened to a torque of 27 Nm.

5.2 Control Systems

5.2.1 Gas flow control

The set points for the control system are chosen for efficient operation at 3250 Amps and have been compromised for zero current operation. At a given current the leads will have a temperature profile and a cold end heat load which is dependent on the gas countercooling. Therefore adjusting the mass flow rate to maintain the temperature of one point on the lead at a constant value, fixes the temperature profile and the cold end heat load.

With the clamps removed, two type T Thermocouples are inserted into the leads from above to a point which is 20% from the warm end. This point has the maximum variation in temperature for changes in mass flow rate. One sensor is redundant and the other is the process variable for the three term Eurotherm 810 controller which adjusts the opening of the valve to regulate the gas flow. The valve itself could fail shut and consequently there is a needle valve in parallel with it which will provide a low gas flow rate to reduce the rate of temperature rise in such an eventuality.

The controllers have two alarms which should be set to provide a warning if the process variable rises 20 K above the set point and to initiate a rampdown of the magnet if the difference is 40 K. The rotameters which measure the flow of helium gas in each lead have minimum flow detectors which would latch in an alarm condition and should be used to initiate a rampdown in such a situation. A reset button is provided in the CLSCC, see section 5.2.3 below.

If, during a loss of coolant condition, a rampdown was only initiated by the second Eurotherm alarm operating at 140 K (the minimum flow detectors having failed to operate) then the leads would see a maximum temperature of 300 K as recorded on the type T thermocouples.

Figure 5.2 gives the operating characteristics of the lead and shows the cold end heat load for the set point and the volumetric flow of helium at STP for cold end heat load. The higher set point will result in the minimum refrigerator load at the full operating current of 3250 Amps. During a fridge outage condition the need is to maximise the endurance of the magnet with less regard to the amount of gas returned at room temperature. Thus the leads are operated at the lower set point using cold gas generated on the solenoid to overcool the leads and thus reduce the cold end heat load.

5.2.2 Warm End Heat Load Control Systems.

To provide a margin of safety as a precaution against the loss of coolant condition the leads are run in a slightly overcooled condition. As such there is a heat load at the warm end terminations which is of the order of 100 Watts. This heat is supplied by 400 Watt cartridge heaters inserted into each of the warm end terminations and powered independently by Omron on/off controllers measuring the process variable on type K thermocouples close to the cartridge heaters. The set point should be set to 30°C which will prevent condensation forming.

A band alarm will provide a pair of contacts which will open with an alarm condition.

5.2.3 Location of control system

The entire control system and flow detectors for both leads are housed inside the CLSCC which is adjacent to the service turret on the magnet. The systems are fully automatic, the only requirement being to select the second set point for a fridge outage condition by a remote switch in the control room. All the alarm contacts are closed in the safe condition and open for the alarm condition. The redundant type T thermocouple in the leads could provide a signal for monitoring the temperature of the leads if this is required in the control room. During normal operation there should be no need to gain access to the control systems inside the CLSCC except to reset the minimum flow alarms by pressing the black button on the grey alarm boxes in the top right hand corner of the CLSCC.

All the thermocouple leads have wire braid to provide shielding against electrical noise.

5.3 Ratings and Protection

5.3.1 Gas Flow Control System

The temperatures for the set points and the alarms and the flow rate for the minimum flow detectors are illustrated in Figure 5.2. The flow rate in each needle valve should be 25 l/min when the dewar pressure is normal and stable. The control terms for the 810 controllers are therefore as follows

LS	Set Point 2 (Normal Operation)	88 K	
A1	alarm 1	100 K	(Not available prior to commissioning on site)
A2	alarm 2	110 K	
Rb	Xp%	6%	
t_1	T. int. (secs)	300 sec.	
td	T. deriv (secs)	25 sec.	
Hc	cyc. tim. (secs)	0.3 no option	
Hl	Max power (heat)	100%	
Set Point 1 (Fridge Outage)		67 K	

All the parameters except Set Point 1 can be locked by the switch on the rear of the controller. This set point is used for the fridge outage condition so that there is scope to adjust this set point to optimise endurance or reduce the ambient temperature gas going into the recovery system.

5.3.2 Warm End Heating

The hysteresis setting on the Omron controller should be adjusted so that the cycle times are as long as possible for an acceptable temperature deviation from the set point. The deviation meter reads a percentage of the full scale of 399°C. Before leaving the factory the controllers were adjusted to give a dead band of 2°C.

The band alarm has been set at about 3% or ± 20°C.

5.3.3 Loss of Coolant Condition

With one alarm and one rampdown trip triggered by temperature and another rampdown trip triggered by a minimum flow condition it is unlikely that the lead temperature will ever rise above room temperature. If however the temperature on the leads has risen above 300 K and no rampdown has been started then an emergency rampdown of the current must be initiated. Without this there is a possibility of a quench propagating from the leads or of some damage to the leads as the temperature continues to rise. This will happen over a timescale conservatively estimated as 50 minutes after the loss of coolant or about 20 minutes after a temperature of 300 K has been reached.

Although the potential drop on the leads is not used for control of the gas flow it does provide a useful measure of the temperature profile along the leads. At normal operation the P.D is 40 mV. If the temperature at any point on the leads rises, the P.D increases. For example 20 minutes after a loss of coolant condition the P.D is 80 mV. Thus, even though during a loss of coolant condition the temperatures of the two ends stay the same, measuring the P.D will identify if the temperature profile has risen above its normal condition.

6 COIL POSITIONING SYSTEM

6.1 Description of Radial Supports

The coil and the radiation screen are supported by 16 radial rods, 8 at each end of the coil acting in directions essentially at 90° to the coil horizontal axis. The support rods are bellows - sealed through to the vacuum space and each is attached to a 90° geared jack unit which is operated by an axially aligned shaft. The axial shafts are extended to the outside of the iron core where a mechanical counter is used as a measure of the coil position. A coil movement of 1 mm corresponds to 4 turns of the axial shaft and this registers as 40 digits on the mechanical counter. As the jacks are handed (left and right) there is a label attached to each mechanical counter with an arrow showing the direction which will increase the tensile load in the support rod. As the support rods must not be allowed to take any compressive load there are slotted holes provided in the 16 brackets which are attached to the coil shell. This allows 3 mm travel between the 'tension' position and the compressive position. Note that it is very important to avoid significant compressive loads in the radial supports as this could cause buckling of the rods.

Each radial jack unit has a strain gauge load sensor which is used to monitor the load in each support; this is displayed, in Kg, on the strain gauge bridge unit. Tension values are positive and compression values are negative; as the bellows unit has a small spring rate and as the radiation screen is also supported from the same jack units, it is usually not practical to obtain a true zero reading on the indicator to correspond to no load in the coil support rod. The procedures given below for the adjustment of the coil position allow for this lack of a true zero reading.

6.2 Description of Axial Supports

At the east end of the coil (services end) there are four axial struts (T, V, W and X) which accept tension and compression loads. The struts are bellows - sealed through to the vacuum space and each is connected to an extension rod which terminates at the outer face of the coil collar in an axial load cell. All position adjustments are made local to the load cell by means of 5 bolts at each cell - two bolts cause tension and three bolts cause compression.

The measurement of the axial position of the coil is made at each of the four axial struts reading from the outer face of the cryostat end plate (east end) to the face of the load cell. The location of the radial and axial support units are given by drawing AJE1005 sheet 3, part of which is shown in Figure 6.1.

6.3 Datum Settings

6.3.1 Radial

During assembly and works testing of the magnet, measurements were taken at various stages to assist in the setting-up operations. The most basic datum readings for the radial supports are those taken on the 16 jack units by measuring the depth of the jack rod (A) below the protecting tube (B) as shown, (Figure 6.2). These readings are given in column (1) below, with the coil warm, set up centrally in the vacuum casing and in the correct axial position.

Column (2) gives the corresponding loads in kilogrammes and Column (3) gives the mechanical counter readings. These readings were taken on final assembly at Cornell in LoE building, prior to cooldown.

Radial support reference	Depth of (A) below (B), mm (Column 1)	load kg (Column 2)	Reading on mechanical counter (Column 3)
A	15.2	+ 150	500
B	15.7	+2320	500
C	19.0	+ 170	500
D	16.8	+ 170	500
E	19.3	+ 170	500
F	19.5	+ 180	500
G	17.8	+2240	500
H	20.2	+ 180	500
J	15.3	+ 180	500
K	12.6	+2190	500
L	18.7	+ 180	500

M	13.5	+ 170	500
N	17.0	+ 180	500
P	16.3	+ 180	500
R	16.1	+2330	500
S	18.2	+ 160	500

After the coil is installed in the iron yoke, the radial jack extension rods are inserted through the coil collars with their mechanical counter units set to their datum readings (nominally 00500). If, for any reason, the relationship between the jack and the counter is lost, it can be regained by re-adjusting the jack units to give the dimensions in Table 6.3 Column 1 and re-setting the counters to the correct datum reading prior to inserting the extension rods. Alternatively, the counter reading can be calculated from the jack rod-to-tube measurement 'X', noting that 1 mm of positive travel on the jack corresponds to an increase of 40 digits on the counter, and will cause a reduction in dimension 'X' in Figure 6.2. It is obvious that such a check can only be made when the jacks are accessible and thus it is important that the jacks are not turned without the mechanical counters being engaged.

The maximum radial movement of the coil of ± 10 mm corresponds to ± 40 turns on the jacks and ± 400 digits on the counters. The maximum and minimum counter readings are thus 00900 and 00100.

6.3.2 Axial

The axial position of the coil is found from external measurement. Without the iron yoke present, the correct datum axial position is such that the average dimension 'X' (Figure 6.3) is 132 mm.

With the magnet installed in the iron yoke, two measurements are needed to establish the axial position of the coil. The east end collar has four holes adjacent to the axial supports; these allow for the end face of the vacuum casing to be used as a reference face and the outerface of the axial support load cell as the other reference. Dimension 'X' (Figure 6.4) should be such as to give a mean value of the four readings of 745 mm; this is the datum position with the coil centred axially in the vacuum casing in its 'cold' condition.

The allowed axial movement of ± 5 mm corresponds to maximum and minimum averaged readings for dimension 'X' of 750 mm and 740 mm.

6.4 Shipping and Handling Procedures

6.4.1 Shipping or moving magnet without iron yoke

It is essential that the coil is always supported in an axial direction before it is moved as the radial supports offer no axial restraint and could be easily damaged by excessive axial displacement of the coil. As soon as the iron yoke has been removed, four (white) transit brackets must be fitted to the end of the axial support struts prior to the magnet being moved. The correct setting for these is shown in Figure 6.3 with distance 'X' being 132 mm averaged over all 4 supports.

The four main radial supports B, G, K, R, should all carry an equal load ± 10%. The remaining radial supports, which are nominally at zero load, should be tensioned equally, in pairs, until a torque of 10 lb-ins is needed to operate the jack. This should correspond to a (positive) tensile load on these supports of about 150 Kg.

For well-controlled movement, for example within the LOE and LO buildings at Cornell, there should be no need to provide additional support to the radiation screen. If the magnet is to be moved without special precautions it will be necessary to remove the end plates of the vacuum vessel and provide transit packing between the end plates and the end of the radiation screen in an axial direction; without such packing the axial forces on the radiation screen must be limited to ≈ 0.5 g.

6.4.2 Moving magnet with iron yoke

All radial and axial supports, including the operating or extension rods, should be in place and carrying load. Radial supports B, G, K, R, should all carry an equal load ± 10%. The remaining radial supports, which are nominally at zero load, should be tensioned as described above in 6.4.1. The axial supports T, V, W, X, should all carry an equal load ± 10%

6.4.3 Moving dewar

The helium dewar has three transit support jacks, aligned radially, and accessible via NW 50 flanges when the dewar vacuum space has been aired up.

These supports should be wound in to touch the 4 K vessel before the dewar is moved and restored after such movement. Care must be taken to ensure the cryostat vacuum is aired-up before the vacuum sealing blanks are removed.

6.5 Cooldown Procedures

The coil support system must, of necessity, be very rigid to prevent unstable movement of the coil when the coil is energised and magnetic de-centring forces apply. During cooldown it is necessary to monitor the load on the radial and axial supports and to make adjustments to avoid excessive forces which could arise from high differential temperatures during cooldown.

In the case of the axial supports, the two lower supports (X and W) must be relieved of load by slackening off the 5 adjusting screws at each point, by 1 mm prior to the start of cooldown. ***It is essential that these supports are secured as described in section 6.6.1 when the coil is cold and before the coil is energised.***

The radial supports are designed to 'lock-up' slightly as the coil cools down. This is intentional as it allows the coil radial supports to be finally adjusted whilst the coil is cold and thereafter no further adjustment is needed on cooldown or warm-up.

6.5.1 Initial Cooldown

On the initial cooldown, the non-load carrying supports should be released by a small amount as registered by the mechanical counters:

C, F, L and P should be decreased by 25 units (0.625 mm).

A, D, E, H, J, M, N, S should be decreased by 15 units (0.375 mm).

As the initial cooldown is in progress the loads in all supports (radials and axials) should be monitored and any excess loads relieved by appropriate adjustments. It is important to avoid compressive loads greater than 200 Kg in the radial supports (negative values on indicator unit).

When the coil and the radiation screen are at their correct temperature, the radial supports must be re-tightened:
C, F, L and P should be increased roughly equally until they are showing a tension of nil to 50 Kgs and a similar procedure is followed for the support pairs:

A and H
D and E,
J and S,
M and N.

In making these adjustments, it is possible to detect the point at which the jack starts to tension the coil support rod: a torque of 5 lb-ins is needed to rotate the jack shaft at no-load. This increases to 7 to 8 lb-ins as the load is applied. the torque-load relationship of the radial jacks is shown in Figure 6.5 and this can be used to cross-check the load cell indications, if need be.

The axial supports X and W should be secured so that all axial supports are carrying an equal load ± 10%.

6.5.2 Subsequent Cooldown

Prior to cooldown, axial supports X and W must be released by slackening off by 1 mm the 5 adjusting screws at each point. The loads in all radial and axial supports need to be monitored but there should be no need to relieve the radial supports of load as described in 6.5.1 above. The exception to this would be the case where the radial supports have been adjusted whilst the coil was above 50K and if this has been done it would be necessary to treat the cooldown as an initial cooldown (see 6.5.1).

When cooldown is complete, the axial supports X and W must be secured so that all axial supports are carrying an equal load ± 10%.

6.6 Adjustment of Coil Position within Cryostat

Whenever the coil is being re-positioned, the load cells must be monitored by the bridge unit to avoid excessive loads or, for the radial supports, compressive loads being applied. All adjustments must be made with the coil un-energised and at a uniform and steady temperature, and preferably below 40 K. The procedures are the same whether the iron yoke is present or not - with the exception that the axial load cells are not used for the air-cored works testing.

Sections 6.6.1 to 6.6.13 refer to the use of the radial load cells in setting up the nominally unloaded radial supports. As a back-up to this, it is possible to check the load taken by the radial supports by measuring the torque needed to adjust the jack. The correlation found during works testing is shown in Figure 6.5.

6.6.1 Moving the coil axially

a) Determine the distance the coil has to be moved.

b) Measure axial position of coil and check the new adjustment will not exceed the allowable limits.

c) Record axial position at support point T.

d) Record the loads in the radial supports J, K, L, M, N, P, R and S.

e) Slacken all 5 bolts securing the load cell mounting plate to the iron yoke at points V, W and X, by several turns.

f) Partially slacken the bolts securing the load cell mounting plate at point T and adjust the bolts to move the coil the required distance. As this is being done, monitor the loads shown by the radial supports J, K, L, M, N, P, R and S. If any of these show a change in load of more than 200 Kg (+ve or -ve), stop making the axial adjustment and make a correction to the radial support(s): if the reading was increasing positive, decrease the load; if the load was negative, increase the load.

g) Re-measure the axial position at point T and if it is now correct, tighten the 5 bolts securing the load cell mounting plate to the iron yoke. This has to be done in sequence and with care to avoid applying tilting forces to the load cell. It is preferable to tighten the three tensile bolts lightly but equally and then apply the two compressive (jacking) bolts. When complete all 5 bolts should be firm, but not overtightened.

h) Return to the radial supports at the west end of the coil and if necessary adjust K and R to carry equal load - the main coil load - and J, L, M, N, P and S to carry a nominal tensile load of between nil and + 50 Kgs tension. The radial supports at the east end of the coil should not require attention.

i) Re-tighten the 5 bolts at support point W in a sequential manner: a light nip to all 5 bolts, followed by a gentle and progressive firming-up operation. In doing this, the load should be shared by T and W so that when complete each should record the same load ± 10% and both must be the same sign (positive or negative).

j) Retighten the 5 bolts securing the load cell at point V, in a similar manner. When complete, the load shown in support V should be the same sign (positive or negative) and should be between ¼ and ½ of the average load shown in T and W.

k) Retighten the 5 bolts securing the load cell at point X, in a similar manner. When complete the load shown in all axial supports should be the same, ± 10%.

l) Check that all bolts securing all load cell plates are firm and that the central bolt securing the load cell to the extension rod is tight.

m) Check that the axial load cell instrumentation plugs are firm in their sockets.

n) Record final readings on all mechanical counters A to S; record loads on all supports A to X.

6.6.2 Moving both ends of coil vertically upwards

If the required movement of the coil is equal at each end, there is no need to touch the axial supports, which simplifies the operation. However if the required movement exceeds 2 mm, it must be done in more than 1 sequence ie two movements of 1.5 mm will be needed to effect a 3 mm movement.

a) Determine the distance that each end of the coil has to be moved, (eg 1.5 mm). Convert this dimension into a counter reading by multiplying by 40, (eg 60).

b) Record the mechanical counter readings at A, B, C, D, E, F, G, H and J, K, L, M, N, P, R, S. It is also useful to record the loads shown in each of the above supports and the axial supports T, V, W, X, as a cross-check if an incorrect sequence is followed. Make a note of the required final readings which would be, for the example given:

B, G, K, R - add 60
C, F, L, P - deduct 60
A, H, J, S - nominal increase (4)) Final position adjustment
D, E, M, N - nominal decrease (4)) is made using load or
torque readings

c) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce C, F, L and P by 10 more than required adjustment (eg 70).

ii) Reduce D, E, M and N by 10.

iii) Operating on all4 jacks simultaneously, increase B, G, K and R by the required amount (eg 60).

iv) Increase A and H equally (eg 4) until they are each taking load as shown by bridge.

v) Increase S and J equally (eg 4) until they are each taking load as shown by bridge.

vi) Increase D and E by roughly equal amount (eg 6) until they are taking load as shown by bridge.

vii) Increase M and N by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

viii) Increase C, F, L and P by 10 until they are taking load, as shown by bridge.

d) Compare the mechanical counter readings with the intended final figures and decide if any errors need to be corrected.

e) Compare the loads shown by the radial and axial supports with the initial readings and correct any significant deviations:

Main supports	B, G, K, R should carry equal load
Axial supports	T, V, W, X should carry equal load
Radial supports	A, C, D, E, F, H, J, L, M, N, P, S should carry nil to + 50 Kgs

f) Record final readings on mechanical counters A to S; record loads on all supports A to X.

6.6.3 Moving both ends of coil vertically downwards

If the required movement of the coil is equal at each end, there is no need to touch the axial supports, which simplifies the operation. However if the required movement exceeds 2 mm, it must be done in more than 1 sequence ie two movements of 1.5 mm will be needed to effect a 3 mm movement.

a) Determine the distance that each end of the coil has to be moved, (eg 1.5 mm). Convert this dimension into a counter reading by multiplying by 40, (eg 60).

b) Record the mechanical counter readings at A, B, C, D, E, F, G, H and J, K, L, M, N, P, R, S. It is also useful to record the loads shown in each of the above supports and the axial supports T, V, W, X as a cross-check if an incorrect sequence is followed. Make a note of the required final readings which would be, for example given:

B, G, K, R - deduct 60
C, F, L, P - add 60
A, H, J, S - nominal decrease (4)) Final position
D, E, M, N - nominal increase (4)) adjustment is made
using load or torque
readings

c) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce A, H, J and S by 10.

ii) Operating on all4 jacks simultaneously, decrease B, G, Kand R by the required amount (eg 60).

iii) Increase D and E equally (eg 4) until they are each taking load as shown by bridge.

iv) Increase M and N equally (eg 4) until they are each taking load as shown by bridge.

v) Increase A and H by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

vi) Increase S and J by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

vii) Increase C,F, L andP by (eg 60) until they are taking load, as shown by bridge.

d) Compare the mechanical counter readings with the intended final figures and decide if any errors need to be corrected.

e) Compare the loads shown by the radial and axial supports with the initial readings and correct any significant deviations:

Main supports	B, G, K, R should carry equal load
Axial supports	T, V, W, X should carry equal load
Radial supports	A, C, D, E, F, H, J, L, M, N, P, S should carry nil to + 50 Kgs

f) Record final readings on mechanical counters A to S; record loads on all supports A to X.

6.6.4 Moving both ends of coil horizonally to north

If the required movement of the coil is equal at each end, there is no need to touch the axial supports, which simplifies the operation. However if the required movement exceeds 2 mm, it must be done in more than 1 sequence ie two movements of 1.5 mm will be needed to effect a 3 mm movement.

a) Determine the distance that each end of the coil has to be moved, (eg 1.5 mm). Convert this dimension into a counter reading by multiplying by 40 (eg 60).

b) Record the mechanical counter readings at A, B, C, D, E, F, G, H and J, K, L, M, N, P, R, S. It is also useful to record the loads shown in each of the above supports and the axial supports, T, V, W, X, as a cross-check if an incorrect sequence is followed. Make a note of the required final readings which would be, for the example given:

A, D, N, S - add 60 40
E, H, J, M - deduct 60
B, C, P, R - nominal increase (4))
F, G, K, L - nominal decrease (4))

Final position adjustment is made using load or torque readings

c) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) ReduceE, H, J and M by 10 more than required adjustment (eg 70).

ii) Reduce C, F, L, P by 10
Reduce G, K by 4
Increase B, R by 4

iii) Operating on all 4 jacks simultaneously, increase A, D, N and S by the required amount (eg 60).

iv) Increase E and H equally (eg 10) until they are each taking load as shown by bridge.

v) Increase M and J equally (eg 10) until they are each taking load as shown by bridge.

vi) Increase C and P by 14 and increase F and L by 6 until they are taking load, as shown by bridge.

d) Compare the mechanical counter readings with the intended final figures and decide if any errors need to be corrected.

e) Compare the loads shown by the radial and axial supports with the initial readings and correct any significant deviations:

Main supports	B, G, K, R should carry equal load
Axial supports	T, V, W, X should carry equal load
Radial supports	A, C, D, E, F, H, J, L, M, N, P, S should carry nil to + 50 Kgs

f) Record final readings on mechanical counters A to S; record loads on all supports A to X.

6.6.5 Moving both ends of coil horizontally to south

If the required movement of the coil is equal at each end, there is no need to touch the axial supports, which simplifies the operation. However if the required movement exceeds 2 mm, it must be done in more than 1 sequence ie two movements of 1.5 mm will be needed to effect a 3 mm movement.

a) Determine the distance that each end of the coil has to be moved (eg 1.5 mm). Convert this dimension into a counter reading by multiplying by 40 (eg 60).

b) Record the mechanical counter readings at A, B, C, D, E, F, G, H and J, K, L, M, N, P, R, S. It is also useful to record the loads shown in each of the above supports and the axial supports T, V, W, X as a cross-check if an incorrect sequence is followed. Make a note of the required final readings which would be, for example given:

E, H, J, M - add 60

A, D, N, S - deduct 60

F, G, K, L - nominal increase (4) final position adjustment
B, C, P, R, - nominal decrease (4) is made using load or torque readings

c) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) ReduceA, D, N and S by 10 more than required adjustment (eg 70).

ii)

Reduce	C, L, F, P	by 10
Reduce	B, R	by 4
Increase	G, K	by 4

iii) Operating on all4 jacks simultaneously, increase E, H, J and M by the required amount (eg 60).

iv) Increase A and S equally (eg 10) until they are each taking load as shown by bridge.

v) Increase D and N equally (eg 10) until they are each taking load as shown by bridge.

viii) Increase F and L by 14 and increase C and P by 6 until they are taking load, as shown by bridge.

d) Compare the mechanical counter readings with the intended final figures and decide if any errors need to be corrected.

e) Compare the loads shown by the radial and axial supports with the initial readings and correct any significant deviations.

Main supports	B, G, K, R should carry equal load
Axial supports	T, V, W, X should carry equal load
Radial supports	A, C, D, E, F, H, J, L, M, N, P, S should carry nil to + 50 Kgs

f) Record final readings on mechanical counters A to S; record loads on all supports A to X.

6.6.6 Moving east end of coil vertically upwards

This operation involves a tilting of the coil axis and a corresponding variation in the axial supports, two of which would need to shorten and two would lengthen. The simplest procedure (operations a) to f) and k) to p) below) will result in the coil moving axially by an amount approximately equal to 40% of the intended radial movement, ie a 1.5 mm radial movement at one end will also displace the coil axially 0.6 mm. If this axial movement can be accepted, the movement sequence may omit operations h), i) and j); otherwise the full procedure must be followed to restore the coil's axial position.

If the required radial movement exceeds 2 mm, it must be done in more than one sequence, ie two movements of 1.5 mm will be needed to effect a 3 mm movement.

a) Determine the distance that the east or west end of the coil has to be moved, (eg 1.5 mm). Convert this dimension into a counter reading by multiplying by 40, (eg 60).

b) Record the mechanical counter readings at A, B, C, D, E, F, G and H. It is also useful to record the loads shown in each of the radial and axial supports as a cross-check if an incorrect sequence is followed. Make a note of the required final readings which would be, for the example given:

B and G - add 60
C and F - deduct 60
A and H - nominal increase (4))
D and E - nominal decrease (4))

Final position adjustment
is made using load or
torque readings

Record the axial position of the coil as an average of the four readings taken at positions T, V, W and X.

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points X and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce C and F by 10 more than required adjustment (eg 70).

ii) Reduce D and E by 10

iii) Operating on both jacks simultaneously, increase B and G by the required amount (eg 60).

iv) Increase Aand H equally (eg 4) until they are each taking load as shown by bridge.

v) Increase D and E roughly equal amounts (eg 6) until they are taking load as shown by bridge.

vi) Increase C and F until they are taking load, as shown by bridge.

e) Compare the mechanical counter readings with the intended final figures and decide if any errors need to be corrected.

f) Compare the loads shown by the radial supports with the initial readings and correct any significant deviations:

Main supports	B, G, K, R	should carry equal load
Radial supports	A, C, D, E, F, H, J, L, M, N, P, S should carry nil to + 50 Kgs	

Note: at this stage the axial supports are either to be adjusted (operations g) to q)) or the coil is secured in the existing axial position (operations g) and k) to q)).

g) Measure the axial position of the coil taken at all 4 positions T, V, W and X.

h) Release the 5 bolts on axial supports V, W and X and adjust the coil position at point T so that the average figure from all 4 positions corresponds with the previously measured figure.

i) Tighten the 5 bolts securing the load cell mounting plate at position T. This has to be done in sequence and with care to avoid applying tilting forces to the load cell. It is preferable to tighten the three tensile bolts lightly but equally and then apply the two compressive (jacking) bolts. When complete all 5 bolts should be firm but not overtightened.

j) Retighten the 5 bolts at support point W in a sequential manner: a light nip to all 5 bolts followed by a gentle and progressive firming up operation. In doing this, the load should be equally shared by T and W so that when complete each should record the same load ± 10% and both must be the same sign (positive or negative).

k) Retighten the 5 bolts securing the load cell at point V, in a similar manner. When complete, the load in support V must be the same sign (positive or negative) and should be between ¼ and ½ of the average load shown in T and W.

l) Retighten the 5 bolts securing the load cell at point X; in a similar manner. When complete the load shown in support X should be the same sign and equal to the load in support V.

m) Compare the loads shown by the axial supports with the initial readings and correct any significant deviations: Axial supports T, V, W and X should carry equal load.

n) Check that all bolts securing all load plates are firm and that the central bolt securing the load cell to the extension rod is tight.

o) Check that the axial load cell instrumentation cables are firm in their sockets.

p) Record final readings on mechanical counters A to S; record loads on all supports A to X.

6.6.7 Moving east end of coil vertically downwards

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

C, F - add 60

B, G - deduct 60
E, D - nominal increase (4)) Final position
A, H - nominal decrease (4)) adjustments is made using load or torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points X and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce A and H by 10.

ii) Operating on both jacks simultaneously, reduce B and G by the required amount (eg 60).

iii) Increase D and E equally (eg 4) until they are each taking load as shown by bridge.

iv) Increase A and H by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

v) Increase C and F by 60 until they are taking load, as shown by bridge.

Now refer to section 6.6.6, paragraphs e) to end.

6.6.8 Moving east end of coil horizontally to north

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

A, D - add 60
E, H - deduct 60
B, C - nominal increase (4)) Final position adjustment
F, G - nominal decrease (4)) is made using load or torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points V and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

  i) Reduce E and H by 10 more than required adjustment (eg 70).

  ii) Reduce C and F by 10. Reduce G by 4, increase B by 4.

  iii) Operating on both jacks simultaneously, increase A and D by the required amount (eg 60).

  iv) Increase E and H equally (eg 10) until they are each taking load as shown by bridge.

  v) Increase C by 14 and F by 6 until they are taking load, as shown by bridge.

Now refer to section 6.6.6 paragraphs e) to end.

6.6.9 Moving east end of coil horizontally to south

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

E, H - add 60
A, D - deduct 60
F, G - nominal increase (4)) Final position
B, C - nominal decrease (4)) adjustment is made
using load or
torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points V and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

   i) Reduce A and D by 10 more than required adjustment (eg 70).

   ii) Reduce C and F by 10. Reduce B by 4, increase G by 4.

   iii) Operating on both jacks simultaneously, increase E and H by the required amount (eg 60).

   iv) Increase A and D equally (eg 10) until they are each taking load as shown by bridge.

   v) Increase F by 14 and C by 6 until they are taking load, as shown by bridge.

   Now refer to section 6.6.6 paragraphs e) to end.

6.6.10 Moving west end of coil vertically upwards

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6, note that the final readings of the counters, for a movement of 1.5 mm, would be:

K, R - add 60
P, L - deduct 60
J, S - nominal increase (4)) Final position adjustment
M, N - nominal decrease (4)) is made using load or
torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points X and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

   i) Reduce P and L by 10 more than required adjustment (eg 70).

   ii) Reduce M and N by 10.

iii) Operating on both jacks simultaneously, increase K and R by the required amount (eg 60).

iv) Increase Jand S equally (eg 4) until they are each taking load as shown by bridge.

v) Increase M and N by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

vi) Increase L and P by 10 until they are taking load, as shown by bridge.

Now refer to section 6.6.6 paragraphs e) to end.

6.6.11 Moving west end of coil vertically downwards

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

L, P - add 60
K, R - deduct 60
M, N - nominal increase (4))
J, S - nominal decrease (4))

Final position adjustment is made using load or torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points X and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce J and S by 10.

ii) Operating on both jacks simultaneously, reduce K and R by the required amount (eg 60).

iii) Increase M and N equally (eg 4) until they are each taking load as shown by bridge.

iv) Increase J and S by roughly equal amounts (eg 6) until they are taking load as shown by bridge.

v) Increase L and P by 60 until they are taking load, as shown by bridge.

Now refer to sections 6.6.6 paragraphs e) to end.

6.6.12 Moving west end of coil horizontally to north

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

N, S -	add 60	
J, M -	deduct 60	
P, R -	nominal increase (4))	Final position adjustment is made using load or torque readings
K, L -	nominal decrease (4))	

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points V and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce J and M by 10 more than required adjustment (eg 70).

ii) Reduce L and P by 10. Reduce K by 4, increase R by 4.

iii) Operating on both jacks simultaneously, increase N and S by the required amount (eg 60).

iv) Increase J and M equally (eg 10) until they are each taking load as shown by bridge.

v) Increase P by 14 and L by 6 until they are taking load, as shown by bridge.

Now refer to section 6.6.6, paragraphs e) to end.

6.6.13 Moving west end of coil horizontally to south

Refer to section 6.6.6 above and substitute the following paragraphs c) and d) for those in section 6.6.6; note that the final readings of the counters, for a movement of 1.5 mm, would be:

J, M - add 60
N, S - deduct 60
K, L - nominal increase (4)) Final position
P, R - nominal decrease (4)) adjustment is made
using load or
torque readings

c) Slacken off the 5 bolts securing the axial load cell mounting plates at points V and W, sufficient to allow the movement of the coil eg 3 mm or 1½ turns for a 1.5 mm radial movement.

d) Adjust the radial supports as follows, monitoring the mechanical counter readings:

i) Reduce N and S by 10 more than required adjustment (eg 70).

ii) Reduce L and P by 10. Reduce R by 4, increase K by 4.

iii) Operating on both jacks simultaneously, increase J and M by the required amount (eg 60).

iv) Increase N and S equally (eg 10) until they are each taking load as shown by bridge.

v) Increase L by 14 and P by 6 until they are taking load, as shown by bridge.

Now refer to section 6.6.6 paragraphs e) to end.

6.7 Warm-up Procedures

If a rapid warm-up procedure is followed, it may be necessary to relieve two of the axial supports (V and W) from unwanted load as described in section 6.5 above. For a normal warm up procedure over a period of say 5 days or more, there should be no need to relieve the axial supports from load.

The loads in all supports should be monitored during warm-up, whatever procedure is used, and action taken if the loads start to show a noticeable change, of say, more than 200 Kgs.

7 INSTRUMENTATION AND CONTROL

7.1 Temperature Monitoring

7.1.1 Introduction

The automatic temperature monitoring system for the magnet, excluding the monitoring and control of the current leads (see section 5) and the cooldown of the nitrogen screens (see section 3), is based on a Digitrend 245 Datalogger and twenty-seven strategically placed (see section 7.6). Rhodium/Iron cryogenic resistive sensors.

The Digitrend 245 was supplied by

Doric Scientific Division
Emerson Electric Co
3883 Ruffin Road
San Diego
CA 92123-1898

through its associate company - Rosemount Limited of Bognor Regis, England and comprises the following:

1-Digitrend 245 Mainframe with Rh/Fe eprom designated "Special 8101F" (see specification sheet)

1 - Option A Alarm Relay Driver Card
2 - RTD Front End Modules (in CLSCC)
1 - Alarm Relay Panel (in M.C.C)
Interconnecting cables between mainframe and FEMS and between Mainframe and Alarm Relay Panel
1 - Operators Manual
1 - Maintainance Manual
1 - IBM PC Interface Instruction Manual
1 - IBM PC Interface Disk

The Rh/Fe sensors are standard 27Ω resistive cryogenic sensors supplied to the characteristic already provided with individual three point calibrations.

The sensors are calibrated by

Cryogenic Calibration Ltd
Pitchcott
Nr Aylesbury
England

The Digitrend 245 is located in the magnet-control case (M.C.C) and this communicates/drives two Front End Modules (FEM) that are mounted in the current lead stack control case (CLSCC). Each FEM contains a multiplexed constant current source and an analog to digital convertor and are connected via individual 4 lead wires to the temperature sensors. Connections are detailed on AJE 1005 sheets 1 and 2 and the cable routes are shown on the following drawings:

AJE0175	Current Lead Stack Instrumentation
AJE0174	Neck Instrumentation

Two 4 wire screened cables connect to the datalogger. Communication with the datalogger is via a pulse coded 15 KHz signal using a bi-directional link and the FEM receives its power and timing wave form in the form of a 15 KHz signal on the other pair of wires. The Digitrend 245 has the following media available for data output:

1) 9 Digit 7 segment LED display
2) 12-column dot matrix alphanumeric thermal printer
3) Two serial Input/Output ports

The Digitrend 245 has the characteristic curve for the Rh/Fe sensors stored in an eprom memory and this has been given the function number F43. Individual 3 point calibrations for the sensors are given in table 7.1.

7.1.2 Operating

Operating instructions for the Digitrend are given in full detail in the manual provided. (See chapter 4 of Manual). In the following a "D" preceeding a reference number refers to the Digitrend 245 Manual.

7.1.2.1 Switch On

The unit is switched on via the three position keyswitch on the front which also provides selective data logger operation for security. To switch on, insert key and turn to middle detent position. To enable programming capability the key should be turned to the fully clockwise position. After programming the key can be returned to the "on" position and removed to protect against unauthorised change. When initially switched on the datalogger display will flash - steady display by pressing [CLEAR] [RUN] - and the time of switch off and on will appear on the logger printer (see D4.3). All programming is retained by battery backed memory so unless there is a need to change then the only requirement is to clear the asterisk from the log and list print outs - which appears as a reminder of power failure - using the following command.

[CLEAR][PRGM][CLOCK][RUN]

7.1.2.2 Commands

Commands are generally entered via the front panel keyboard although they can be entered via the RS232C serial link (see section 7.1.11) The command structure is detailed in section D4.4 and is generally as follows:

1) All commands begin with [CLEAR] and end with [RUN]

2) All commands have the verb followed by the object as in

   [CLEAR] [LIST] [PRGM] [POINT] [1] [RUN]
   [CLEAR] [DISPLAY] [PRGM] [POINT] [1] [RUN].

The preceeding commands only differ by the means of display of point programming - the first produces the information on the printer the second on the display.

The full list of standard commands available are detailed in D4.6 D4.7 and D4.8.

The following is a short summary of the main commands when entered via the datalogger keyboard.

DISPLAY COMMANDS

FUNCTION	COMMAND	PAGE
Display Day Calender/ 24 hour clock	[CLEAR] [DISPLAY] [CLOCK] [RUN]	D4.20
Display Point Values	[CLEAR] [DISPLAY] [POINT] [point no(s)] [RUN]	D4.20
Display Point Programming	[CLEAR] [PRGM] [POINT] [point no(s)] [RUN]	D4.20
Cancel Display	[CLEAR] [RESET] [DISPLAY] [RUN]	D4.22

The foregoing display the required information on the LED display

LIST COMMANDS

FUNCTION	COMMAND	PAGE
List Day Calender/ 24 hour time	[CLEAR] [LIST] [device code(s)] [CLOCK] [RUN]	D4.24
List User Jobs/Device Errors	[CLEAR] [LIST] [device code(s)] [PGRM] [RUN]	D4.24
List Point Programming	[CLEAR] [LIST] [device code(s)] [PGRM] [POINT] [point no(s)] [RUN]	D4.27

Cancel List in progress	[CLEAR] [RESET] [LIST] [RUN]	D4.33

LOG COMMANDS

FUNCTION	COMMAND	PAGE
Log point data immediately	[CLEAR] [LOG] [device code(s)] [POINT] [point no(s)] [RUN]	D4.34
Log point data periodically	[CLEAR] [LOG] [device code(s)] [POINT] [point no(s)] [CLOCK] [time interval] [RUN]	D4.35
Log point data automatically	[CLEAR] [LOG] [device code(s)] [POINT] [point no(s)] [FUNC] [minute/hour/day code no] [RUN]	
Cancel/Reset Log in Progress	[CLEAR] [RESET] [LOG] [RUN]	D4.39

These log the required information on the internal printer.

Note: DEVICE CODES

1 = Internal Printer
2 = Term 1 Serial Device
3 = Not Used
4 = Term 2 Serial Device

By default log or list is to the requesting device.

MINUTE/HOUR/DAY CODE NUMBERS

6 = Log every minute on the minute
7 = Log every hour on the hour
8 = Log every day at midnight

7.1.2.3 Correcting Key Entry Mistakes (D4.4.1)

To correct a key incorrectly pressed then press [RESET] to clear key entry. However an [ENTER] keystroke cannot be erased in this way and the whole command has to be reentered beginning with [CLEAR]. The datalogger will indicate incorrectly entered portions of a command by flashing the offending section on the display. Press [RESET] to clear the error display and continue with correct command. Entry errors or fault conditions are conveyed by an error code message on the display (see D4.4.1 for a full list of codes and their meanings)

7.1.2.4 Standard Reset Commands (D4.10)

To cancel a command that has been entered ([RUN] already pressed) then the following commands must be entered.

[CLEAR] [RESET] [user job no] [RUN]

To execute this command the user job no for the offending command must be known. To get a list of user jobs (D4.8.2) enter the following command.

[CLEAR] [LIST] [PRGM] [-] [RUN]

If the [-] sign is omitted then the list will contain information on the CRC (Cyclical Reduncancy Check) and switch numbers. From the list so produced the offending job number can be used in the previous command to cancel that job.

To cancel all jobs of a particular type (list, log or display see command summary 7.1.2.2).

7.1.2.5 Special Keys (D4.4.3)

<u>The Hyphen Key</u>

This multi-function key is used

a) as a negative sign for a numerical value [-] [4] [5]

b) as a separator between numbers in a specified range
[POINT] [1] [-] [20]

c) as a separator between commands in serial port programming

d) in certain commands to provide variations
[PRGM] [POINT] [1] - [10] [SKIP] [-]

The Enter Key

This is used as a group delimiter to separate up to four contiguous groups of numbers or four separate numbers

[1] [-] [11] [ENTER] [15] [-] [20] OR
[20] [ENTER] [30] [ENTER] [40]

Paper Feed/Lamp Test (The Paper Key)

This is used to feed paper and test all lamps on the display.

Incrementing/Decrementing Point Data (HI and LO keys)

These are used to increment and decrement the displayed point data. They are also used in alarm programming to indicate alarm sense (D5.2.2.1).

7.1.3 Point Numbers

To improve the speed of logging for quench it has been necessary to divide the coil shell sensors between the two FEMS equally. The point numbers and schematic positions can be found from AJE 1005 sheet 2 and the physical positions can be found from AJE 0075, 0076, 0092,0174 and 0175.

To provide the capability of monitoring the sorb temperature above 300K - the maximum temperature on the Rh/Fe sensor characteristic - each sorb sensor has been connected to two channels on FEM2. Thus channels 33 and 38 are connected to sorb 1 and channels 34 and 39 are connected to sorb 2. TS33 and 34 have been assigned the standard 4 wire Rh/Fe characterstic (F43). To enable the sorb temperature to be monitored above 300 K a special function, designated F45, has been created see D5.3.6. This function uses function 3 (a mV input) as its base function. Then a straight line approximation to the Rh/Fe characterstic above 300 K has been assigned to points 38 and 39 using function 107 (D5.3.5) to provide scaling and offset (see table 7.1 for function 107 constants for all sensors).

7.1.4 Maximum User Jobs Capacity (D4.5.2)

There is a maximum of 15 user jobs available on the Digitrend from the following list

USER JOB	COMMENTS
Display	Display data on front panel readout
Log	Demand log (manual)
User-programmed Timed Interval Log	Maximum of 10 (periodic logs)
Standard Time Interval Log	Every minute, hour, and/or day
Alarm Log	---
Contact Status Monitoring	---
Sequence of Events Recording	---
Point Average/Group Average/ Point Difference/Floating Alarm limits/Rate of Change	System needs may dictate using any given function more than once. Each time a function is used, it counts as a user job.

It is important to keep in mind the following when using your data logger:

* No more than fifteen user jobs can be active at any one time.

* No more than ten user jobs can use programmed time intervals (ie interval log commands).

If you try to execute a command with all 15 user job slots full, your data logger will tell you that it cannot execute the command by an "Error 05" display message. You will then have to reset (cancel) an existing low priority user job in order to make room for another. For example, you can reset the display (which normally is not urgent) in order to provide a log of points in alarm. To reset user jobs, refer to D4.8.6 and D4.10.

7.1.5 Alarms (D5)

Alarms are implemented in the following manner

1) Alarm limit values are assigned to specific alarm limit numbers. (D5.2.2).

2) Alarm limit numbers are assigned to data points (D5.2.3) (upto 4 HI or LO alarm limit values in any combination can be assigned to each data point). When limit numbers are assigned to a data point they are addressed on setting numbers (S1 through S4) to allow unique relay assignment.

3) Relays are assigned to data points (D5.2.5) independently of the limit numbers and there are 16 relays (RY0 to RY15) available on the relay panel supplied. The master relay (RY0) is not available for assignment as this trips/untrips with any point that goes in/out alarm. Each data point can store four relay number assignments coinciding with setting numbers S1 through S4. A setting number assigned to a relay will cause the relay to trip when an alarm condition is detected on that setting number.

The programmed alarm limits are detailed in section 7.5 of this manual.

The alarm relay driver card has been configured (D5.2.4.1) for annuciation sequence ISA A-4-5. The following sequence of commands will program an alarm of 4.6 K over points 1-6 and 21 - 26 with relay 1 being activated.

[CLEAR] [PRGM] [ALARM] [1] [HI] [00046] [RUN]
Assigns limit number 1 to 4.6 K and alarms when data point above this value
[CLEAR] [PRGM] [POINT] [1] [-] [6] [ENTER] [21] [-] [26] [ALARM] [1] [-] [0] [-] [0] [-] [0] [RUN]
Assigns setting number 1 on data points 1 to 6 and 21 to 26 to limit number 1 - all other settings numbers are deprogrammed.

[CLEAR] [PRGM] [POINT] [1] [-] [6] [ENTER] [21] [-] [26] [ALARM] [FUNC] [1] [-] [0] [-] [0] [-] [0] [RUN]

Assigns relay number 1 to setting number 1 on data points 1 to 6 and 21 to 26 - all other setting numbers are deprogrammed.

There are three methods of logging points in alarm apart from the normal logging of points (which would not indicate an alarm if the point went into and then returned from the alarm condition).

a) On demand - [CLEAR] [LOG] [device code(s)] [POINT] [ALARM] [point no(s)] [RUN]

b) Periodic - [CLEAR] [LOG] [device code(s)] [POINT] [ALARM] [point no(s)] [CLOCK] [time interval] [RUN]

c) On transition - when alarm is detected the data point value and its limit status are shown. There are three types of alarm transition logs as described in D5.2.6.1 and these priority logs can be used to interrupt normal logs or printouts.

   Alarm limits can be skipped by using the following command [CLEAR] [PRGM] [ALARM] [limit no(s)] [SKIP] [RUN] and unskipped by inserting [-] between [SKIP] and [RUN].

7.1.6 Maths functions

A variety of maths functions are available on the data logger and these are detailed in D5.3

7.1.7 Mainframe configuration (D3.9)

The following are the configuration switch settings as supplied.

SWITCH NUMBER	SETTING	EFFECT
1	Open	High sensitivity
2	Closed	Time intervals specified in mins/seconds - 9959 - specifies 99 mins and 59 seconds
3	Closed	Normally would display data in °C but the

		datalogger displays in K
4	Open	Reference junction compensation enabled but not used for this type of sensor
5	Closed	Enables CPU serial I/O port programming
6	Open	Enables the ability to program the enable/ disable status (see D4.11.3) of both serial I/O ports.
7	Unused	
8	Unused	
9	Closed	Diagnostic messages are allowed to output as well as listing of closed configuration switches during a program listing (D4.7.6).
10	Unused	
11 and 12	Closed	Selects normal environment for EMI and RFI. User jobs table resets only after watchdog circuit triggers reset four times in an hour.

7.1.8 Program Settings

As supplied the data logger has the following settings programmed.

a) Points 1 to 13 and 21 to 34 are assigned to function 43 with scaling and offsets as listed in table 7.1.

b) Points 14 to 20, 35 to 37 and 40 to 500 are skipped (see D4.6.3)

c) Only serial I/O port 1 is enabled - (see D4.6.5) - see 7.1.11 for the RS232C setup parameters.

d) Alarms are set on the coil shell, radiation screen and sorb temperature sensors (see 7.5 for details).

7.1.9 Cooldown Temperature Monitoring

During cooldown of the magnet it is recommended that the temperatures on the coil shell and radiation screens are monitored and logged every hour. The following command will log (to the printer) all data points once an hour on the hour.

```
[CLEAR] [LOG] [POINT] [1] [-] [13] [ENTER] [21] [-] [34] [FUNC] [7] [RUN]
```

Prior to commencing cooldown alarm limits 1 to 4 should be skipped using the following command (see D5.2.2.2).

```
[CLEAR] [PRGM] [ALARM] [1] [-] [4] [SKIP] [RUN]
```

During cooldown temperature differentials between sensors should be monitored and if exceeded the cooldown process should be held (see 3.2 for necessary action on radiation screen controller). The table in section 7.5 lists the limits and recommended action.

Once the radiation screen has reached its steady state condition then alarm limits 3 and 4 should be unskipped ([CLEAR] [PRGM] [ALARM] [3] [-] [4] [SKIP] [-] [RUN]) and once the coil has reached its steady state then the alarms on this (1 and 2) should also be unskipped.

If the cooldown data is not being logged by a data acquisition system capable of comparing point difference then use the point difference function [function 104 - D5.3.2.2] to log the differences between points periodically. As the number of timed logs is limited to 10 then use this command for the asterisked comparisons listed in the table in 7.5.

7.1.10 Steady State

When both the radiation screen and the coil shell are in their steady operating conditions then all the alarms should be unskipped and the temperatures should be logged every twelve hours. The computer data acquisition system should be monitoring the temperature sensors on a much more frequent basis to ensure that alarms are detected and the appropriate action initiated (see 7.1.11 for Interface to PC and 7.5 for recommended action on alarms).

7.1.11 Interface to Personal Computer

Supplied with the Digitrend 245 is a software package and manual that describes programs for communicating between the datalogger and the IBM PC via the serial RS232C link. This, allied with section D 4.11 of the Digitrend 245 Operators Manual, will provide sufficient information to interface the datalogger using this link. The datalogger is provided with the following programmable parameters set-up (see D4.11.3).

PARAMETER NUMBER	STATE	EFFECT
1	2	Sets port to computer port
2	6	Sets character format
3	1	Line control enabled
4	1	Block control enabled
5	0	Xon control off
6	0	Half duplex
7	169	169 characters per line
8	200	200 lines per block
9	0	No delay in headers or trailers
10	150	Timeout specifies length of time until output of datalogger is disabled when Xon is not received or CTS (Clear to Send)
11	\F	Character sent by datalogger when valid command received
12	\U	Character sent by datalogger when invalid command received
13	\B	Character sent by datalogger to lead every log or list
14	\C	Transmit end of text string
15	17	Xon character specified for datalogger Xon/Xoff control.
16	*	Prompt string that datalogger gives to indicate it is ready for command I/P.
17	Null	No line header specified
18	\M	Line Trailer specified
19	Null	No block header specified
20	Q\M	Block trailer output at end of block
21	19	Xoff character recognised when Xon/Xoff control enabled
22	8	Specifies baud rate at 2400

7.1.12 Specification

Sensor type	27 Ω Rhodium Iron Resistors matched to characteristic curve supplied
Datalogger	
Resolution	0.1°C
Conformity Error	± .05°C
Accuracy	± .015% xrdg + 0.1K

Point to Point Offset Errors of Eprom Characteristic Curve

0.1K	@ 4K
0.33K	@ 27K
0.14K	@ 77K
0.13K	@ 170K above

Input specification

Measurement Technique: Dual slope integrating, auto-zeroing, true differential input, analog to digital conversion; 16 bits; 65,000 count dynamic range.

Multiplexing Method: 20 point Front End Module (FEM); solid state (CMOS).

Measurement Speed:

Points in System	Overall measurement speed
20	2.85 points/seconds
40	5.71 points/seconds

Zero Stability: Patented switching amplifier front end reduces zero offset to $\leqslant 0.5\mu V$.

A/D Reference: Monolithic precision reference. 20 ppm/°C temperature coefficient.

Gain Calibration: Software via programming controls (no potentiometer adjustments).

Output Specifications

Display: 7 Segment, 0.5 inch LED

Indicators: Individual red LED indictors for °F,°C system alarm, point alarm, data/time,I/O error, power, program mode enabled.

Printer: Thermal alphanumeric, 12 columns, 5 x 7 dot maxtrix, 2.5 lines per second minimum, eight lines per inch, (3.1 lines/cm), 260 ft. (78 m) roll or fanfold thermal paper.

Serial I/O Port (2 Standard): Programmable baud rate: 110, 300, 1200, 2400, 4800, 9600 baud.

RS-232-C voltage level or 20 mA current loop (active or passive transmit and receive), field configurable, ASCII code.

Fully user programmable character format and protocol (bits/character; parity; stop bits; delay; full or half duplex, line and block control; header and trailer data, polled or unsolicited modes; etc).

Physical Specifications

Temperature:

Operating: Mainframe and Satellite: 0 to 50°C
Front End Modules: 0 to 70°C.
Storage: -20°C to 80°C.

Humidity:

Mainframe and Satellite: 90% RH non-condensing 0°C to 50°C.

Input Power:

Mainframe: 40 watts typical, 55 watts max
100/130 VAC, 50/60 Hz

Warm-up Time: Two minutes to full accuracy. Accuracy reduced by approximaely 0.01% of range on initial turn-on.

Non-Volatile Memory: 30 days min at 25°C; nickel-cadmium battery trickle charge.

Program Protection: Keylock standard.

FUNCTION 107 CONSTANTS FOR TEMP SENSORS

FUNCTION 107 CONSTANTS m	b	CCL SENSOR No.	DIGI-TREND SENSOR No.	R(Ω) @4.22K	ΔT(K)	R(Ω) @77.35K	ΔT(K)	R(Ω) @273.2K
		1552	1	1.8379	-.0115	6.6759	-.024	27.006
10	1	1553	2	1.8324	-.054	6.6759	-.025	27.009
		1554	3	1.8429	+.027	6.6893	+.114	27.021
		1556	4	1.8279	-.0115	6.6715	-.07	27.012
10	1	1557	5	1.8259	-.1048	6.6709	-.076	26.998
10	1	1558	6	1.8325	-.053	6.6727	-.058	27.004
10	0	1563	7	1.8392	-.0014	6.6783		26.987
10	0	1566	8	1.8396	-.0	6.6843	+.06	27.006
10	2	1574	9	1.8229	-.1281	6.6633	-.154	26.999
10	2	1578	10	1.8228	-.128	6.6576	-.213	27.003
		1628	11	1.8323	-.055	6.6682	+.03	27.01
10	-2	1569	12	1.8573	+.139	6.701	+.234	27.005
10	-2	1573	13	1.853	+.106	6.6997	+.221	27.017
10	1	1559	21	1.8297	-.075	6.667	-.116	26.998
10	1	1562	22	1.8295	-.076	6.6694	-.091	26.992
10	-1	1564	23	1.8468	+.057	6.6887	+.107	27.0
		1572	24	1.8362	-.0247	6.6792	.009	27.002
10	1	1576	25	1.8258	-.1055	6.6666	-.121	27.013
10	1	1571	26	1.8256	-.1071	6.6683	-.102	27.002
10	0	1568	27	1.839	-.002	6.6901	+.12	27.009
10	-1	1575	28	1.839	-.003	6.6841	+.06	27.004
10	+3	1555	29	1.8129	-.206	6.65	-.292	26.994
10	+3	1560	30	1.8139	-.198	6.6482	-.311	26.985
10	+2	1561	31	1.8236	-.122	6.6613	-.175	26.99
10	+1	1565	32	1.8227	-.129	6.6654	-.133	26.997
10	+1	1570	33	1.825	-.111	6.6709	-.077	27.016
10	2	1567	34	1.8151	-.19	6.6523	-.268	27.01
.319	27	1570	38					
.319	27	1567	39					

Table 7.1

7.2 Load Monitoring

7.2.1 Introduction

This monitoring system, located in the magnet control case, is designed to energise, amplify and monitor twenty low frequency full bridge transducers. Each channel is powered from a common, centre tapped bridge power supply, but is allocated its own gain and balance controls. A 4½ digit DVM accepts the monitored output. Two operating modes are possible, Automatic (Scan) or Manual. The selection is toggled by a push button and flagged on an indicator. When in manual, bridges may be zeroed, channels calibrated, etc. In Auto, the microprocessor controlled Scanner sequences through each channel in turn, checking to see if preset limits have been exceeded. If so, front panel LEDs, provided for each channel, indicate the degree of overload. The indications will be maintained throughout the existing and subsequent scans until reset by use of the front panel 'CLEAR' button.

Each channel has two positive limits known as 'High' and 'Shutdown'. Also, the four axial channels have an additional two limits for the negative quadrant in order to detect compression overloads.

The system is designed to operate from 100-120V 60 Hz.

All transducer, (5 pin connectors) trip relay contacts (6 pin clean changeover) and IEC mains connector are fitted on the rear panel (mating connectors are supplied). The analogue output is available for inspection on the monitor front panel via a BNC connector.

All the load sensors (including the 4 axial cells) are wired up following the same pin code on the Tuchel 5 pin connectors. This code is shown in AJE1005 sheet 3. As channels A to S (see Figure 6.1) are reserved for the radial load columns and these columns have positive limit alarms only, both the radial load columns and the axial load cells have been wired in the same signal mode so that tension loads produce a positive trip signal. Conversely, compression loads on the 4 axial cells will trip in the negative overload condition since these 4 channels (T to X) have both positive and negative trip alarms.

7.2.2 Load Sensors

Radial Tie Load Sensors

16 Load sensing columns in 55 ton alloy steel have each been internally straingauged, full bridge, 350 Ohms. Their output signals have been trimmed to the same sensitivity of 1 mV/V at 11,000 lbf. (5,000 Kg) with NBS traceable Calibration/Proof load data sheet issued. The short leadout wires from the internal straingauges are led through the centre of screw actuators and terminated in instrument connectors mounted in 'L' brackets attached to the OVC. The load sensing columns have been well torqued up into a mating thread and alignment bore in the end of each screw actuator, using thread locking compounds.

Axial Load Cells

4 Strainsert flat load cells, model: FL10U(C)-2SG(W)B of 10,000 lbf, working capacity have been supplied with modified, vertical exit short cable leadouts. The load cells are suitable for use up to 5,000 Kg and calibration data is provided. Each cable is terminated in the same type of connector and bracket assembly as the load sensing columns.

Interconnecting Cables

20 screened, 4 core, instrumentation cables have been supplied with identification 'A' to 'X'. Each end of the cable assembly has an identical instrumentation connector (5 pin, Tuchel socket) with a letter marker attached. The 20 cable assemblies are intended to link the 16 radial cells and 4 flat axial cells to the 20 channel data monitoring instrument.

7.2.3 Operation

An internal 4 bit DIP switch, mounted on the Scanner card determines the scan speed when in Auto. Each increment is 0.5

sec. The maximum time per increment is therefore 7.5 seconds.

Switch Number	4	3	2	1	Time/Channel
Value	8	4	2	1	
	0	0	0	1	0.5 sec
	0	0	1	0	1 sec
	1	0	0	0	4 sec
Factory Setting	0	1	0	0	2 sec

The default value, 2 seconds per channel, allows sufficient time for the channel output to be displayed and read by the operator.

7.2.4 Switch On

The system is powered by use of the toggle switch on the left of front panel and indicated by adjacent lamp. The system is in the manual mode at switch on. By use of the direction push buttons, the desired channel may be selected and routed to the DVM. The buttons feature auto-repeat, holding in either button will result in a fast manual scan to the channel required, releasing the button will revert to single step.

Auto

The system is placed into the Auto mode by one press of the 'Auto'/'Manual' push button. (Any unwanted trip indication existing prior to this operation may be cancelled using the 'CLEAR' control).

The scanner will commence always from the last selected channel, sequencing through each channel at the pre-determined rate. Each channel's output will appear on the DVM for the time selected. Outputs found to exceed any trip level will cause:-

1 High (amber) or High and Shutdown (red) LEDs to be

illuminated for the offending channel(s).

2 Trip LED(s) to be extinguished on the relevant trip unit.

3 High or High and Shutdown relay contacts to change over and latch.

The first channel detected as errant will cause the above events. However, the scan will continue as further channels in limit may still be detected on the channel indicators.

Resetting may only be achieved by use of the 'CLEAR' control, or by powering the system off/on. The 'CLEAR' control resets ALL indicators and relays.

7.2.5 Calibration

The system should be set up for operation in the manual mode. Channel zeros and calibrations should be carried out, utilising the individual controls. Note that 'GAIN' controls for each channel have a range of approximately 4:1, ie from x 0.5 to x 2 as a scaling factor on the pre-amplifier gain. The 'ZERO' controls are fitted with two series resistors per channel, 20 KΩ and 30 KΩ. The larger of the two is mounted on turret lugs and may be reduced if greater zero balance range is desired.

A separate load cell calibrator box is supplied and this unit is fitted with a short cable plus Tuchel 5 pin mating connector. The calibrator is used to check the amplifier settings on each of the 20 channels of the Bridge Instrument at suitable periods. In use, the calibrator cable is interchanged with the load sensor connection to the Bridge Instrument and switched to 'zero' position on the cal. selector switch. If the instrument is in use, the sign and value of the signal from the load sensor should be noted. Next, the zero or 'balance' pot should be adjusted until the meter reads 0000. The cal. selector switch is then turned to:

(A) 1 mV/V position for radial cells (A to S), when the meter should be set to read 5000 Kg. Adjust the 'gain' pot, if necessary.

(B) 2 mV/V position for axial (T to X), when the meter should be set to 4550 Kg.

Finally, the noted load value and sign for any channels in use (recorded earlier) should be re-set onto the meter, using the zero balance pot, after re-connecting the load sensors. Naturally it is assumed that only static loading would be present in the load sensors at time of calibration check.

7.2.6 Trip Levels

The trip levels may be set by use of the two 10 turn dials on each of the trip units. The maximum setting on each dial is 10V - equivalent to 10,000 Kg when transducer to system calibration is completed. The FE-285-DTU Trip Unit features front panel LEDs to indicate trip state. These are ON until trip. The four trip settings are known as:-

1) Positive High (Tension High)
2) Positive Shutdown (Tension Shutdown)
3) Negative High (Compression High)
4) Negative Shutdown (Compression Shutdown)

The calibrator may be used to check trip function also if necessary (reverse the green and white signal leads if you wish to check negative trip operation on ch. T to X). Note that operation of the trip circuit causes either amber or both warning lamps to come 'on' and the appropriate green lamp next to the trip pot will go 'out'. These four green lamps are merely to show that the trip section of the circuit is operating. The 'upper' trip pot controls the shutdown relay and the 'lower' trip pot controls the high relay). If it is necessary to alter the scan speed or otherwise gain access to the interior of the Bridge Instrument, the interior chassis may be slid forward (after removing the power cord and all sensor connections), by undoing the 4 front panel mounted retainer screws and pulling the front panel outwards. The circuits are mounted on DIN cards.

7.2.7 Specification

Power requirements 100-120V 60 Hz

For bridge specification and schematic circuit diagrams of load monitor unit see manual supplied 'Fylde 20 channel load cell monitor'.

7.3 HELIUM LEVEL

7.3.1 Operating Instructions

The instrument mounted in the magnet control case monitors the liquid helium level in the dewar by means of a vertical superconductive wire dipping into the liquid. The wire is attached to a PCB supported and protected by a stainless steel tube, which is in turn supported clear of the dewar base, by an O ring seal from the dewar level probe neck tube. Connections to the wire are brought through a 10 pin seal on the end of the tube. With a suitable current flowing, the portion of the wire above the liquid remains in the resistive (non-superconducting) state, whilst the wire immersed in the liquid is in the superconducting state. Under these conditions a measurement of the voltage developed across the wire will indicate what fraction of the wire is above the liquid surface.

To reduce the power dissipated in the dewar, the current is not passed through the wire continuously. Instead the current is switched on for about one second and a reading stored within the instrument. This is then displayed on the meter until the next current pulse. The time between measurements may be varied by the user. A high measurement rate allows a rapidly changing level to be followed whilst a low rate reduces the dissipation within the dewar to a minimum for normal operation. At the low rate the helium boil off due to dissipation is negligible.

A chart recorder output is provided to enable the helium level to be recorded and two change-over relay contacts allow alarms or an automatic top-up system to be operated at preset levels.

7.3.2 Equipment (see AJE 1005 sheet 3)

The equipment comprises the following items:-

1) Indicator unit
2) Sensor Probe
3) Sensor Interconnecting Cable

In addition a liquid helium level meter manual is supplied.

7.3.3 Sampling Rate

The red SAMPLE lamp indicates when a current is being passed through the wire. Between current pulses the meter retains a steady reading corresponding to the liquid helium level at the time of the previous pulse. The interval between sampling pulses may be varied by the SAMPLE RATE switch.

In the HIGH RATE position the interval between pulses is approximately ~~10~~ seconds.
20 (changed Summer 1992 by JJS)

For normal operation where the liquid level is not changing rapidly the LOW RATE may be used to reduce power dissipation. The interval between sampling pulses is then approximately 100 seconds.

For special applications where the liquid level is changing very rapidly and dissipation is not a problem, it is possible to modify the instrument for continuous operation. (See Section 4.7 of the Liquid Helium Level Meter Instruction Manual).

7.3.4 Recorder Output

An analogue output signal is provided at the rear of the instrument for use with a chart recorder in order that the helium consumption may be continuously monitored. An output voltage of zero corresponds to a full dewar (Helium Level = 100%) whilst a voltage of approximately 500 mV is obtained when all the helium is exhausted (Helium Level = 0%). If the recorder has an input impedance of less than 50 k Ohms it will affect the calibration of the instrument by a small amount. This may be corrected for by performing the span calibration described in Section 4.5 of the Instruction Manual with the recorder connected.

7.3.5 Control Output

Two independent change - over relay contacts are provided at the rear of the instrument for the operation of alarms or an automatic filling system. The relays may be set to operate at any two chosen levels by means of an internal adjustment. In addition it is possible to introduce hysteresis on either of the relays by the addition of a single resistor. In this way a single relay may be used to control an automatic filling system. Thus a relay centered to operate at 50% but with 60% of hysteresis incorporated will switch to the low state when the level in the dewar falls to 20%, initiating the filling operation. It will remain in the low state and filling will continue until the level reaches 80% when it will switch back to the high state and the filling process will be terminated. The second relay is then free for use as an alarm, set for example to 10% to indicate that the automatic filling process has failed for some reason.

Sections 4.8 and 4.9 of the Instruction Manual describes the adjustment of the level setting and the addition of hysteresis.

7.3.6 Principle of operation

The sensor relies on the wire in the liquid being more efficiently cooled than the wire in the gas. Thus the joule heating of the resistive section of the wires is sufficient to keep this above its critical temperature where it is in gas but not where it is in liquid. With no current in the wire the entire length will become superconducting. It is therefore necessary to incorporate a small heater resistor in thermal contact with the top of the wire to drive the end of the wire into its resistive state. Provided the current in the wire is sufficient this resistive region will then propogate down the wire to the liquid surface. The probe is shown diagramatically in Figure 7.1.

In operation a constant current is passed through the wire and heater resistor from I+ to I-. The voltage (between V+ and V-) increases as the resistive region propogates down the wire until the liquid surface is reached, at which point a steady value is obtained proportional to the length of wire above the surface of the liquid.

After a time long enough to ensure that the resistive region has reached the liquid surface a sampling pulse stores the final value of the voltage across the wire for display on the meter. Immediately after the sampling pulse the current through the wire is switched off. After a quiescent period of duration determined by the RATE switch, this cycle of events is repeated.

7.3.7 Circuit Description (see Instruction Manual section 3.2)

7.3.8 Calibration (see Instruction Manual section 4)

7.3.9 Specifiction

Serial Number	616-412-25-006
Probe Length	Active length 740 mm, overall length 1340 mm
Sensing system	Superconductive Wire
Probe Diameter	9.5 mm, ⅜ inch
Indication	3 inch moving coil meter
Recorder Output	Approx. 500 mV into 50 k ohms
Control Output	Two changeover contacts operating at preset levels Contact Rating 250 V, 3A AC or DC Maximum Load 80 W DC or 200 VA AC
Accuracy	2% of FSD
*Helium Consumption	
Static	4 ml/hour

On LOW rate	5 ml/hour
On HIGH rate	25 ml/hour
Continuous	150 ml/hour

Sampling Rate

On LOW rate	1 sample per 100 seconds approx.
On HIGH rate	1 sample per 10 seconds approx.

Continuous operation possible by internal adjustment

Magnetic Field	Unaffected by Magnetic Fields up to 4 Tesla
Sensor Temperature	4.2 K ± 1 K

Power Requirements	110 V/60 Hz, 8 VA
Relay 1 Level	10%
Relay 1 Hysteresis	Zero
Relay 2 Level	20%
Relay 2 Hysteresis	Zero

* Since much of the heat conducted down the sensor support tube and generated in the wire is dissipated into the gas rather than the liquid, the helium consumption will vary both with the level of the liquid and the boil-off rate of the dewar itself. The figures quoted correspond to the increase in helium consumption due to a 250 mm long probe in a half full, low-loss magnet cryostat having a static boil off of 80 ml/hour. (These being the conditions under which the increase in boil off due to the level indicator is a maximum).

7.4 VOLTAGE TAPPINGS

The magnet has seven voltage taps at the following positions (see Figure 7.2 and AJE 1005 sheets 1 and 2).

VT1	Centre Tap at crossover point between layers	(AJE0092)
VT2	At coil exit point on Inner Layer (lead A)	(AJE0174)
VT3	At coil exit point on Outer Layer (lead B)	(AJE0174)
VT4	At bottom of current lead A	(AJE0174)
VT5	At bottom of current lead B	(AJE0174)
VT6	At top of current lead A	(AJE0175)
VT7	At top of current lead B	(AJE0175)

The internal coil voltage tap connections are brought up the neck then, after passing through connector H4, they join the voltage taps from the bottom of the Current Leads and follow a spiral route up the outside of a current lead casing before exitting from the vacuum space.

All the voltage taps (including those outside the vacuum space) are brought to screw terminals in the CLSCC.

The voltage taps are rated at 250 V RMS to ground and tested at 500 V DC.

7.5 ALARM AND TRIP FUNCTIONS

Temperature Monitoring - Steady State

The following alarm levels have been set on the Doric datalogger.

POINTS COVERED	LIMIT NUMBER	RELAY NUMBER	ALARM VALUE(K)	ALARM SENSE
TS 1-6 AND 21-26	1	1	4.6	HIGH
TS 7-8 AND 27-28	1	2	4.6	HIGH
TS 9-10	2	3	85	HIGH
TS 11-13 AND 29-32	2	4	85	HIGH
TS 38 AND 39	3	5	373	HIGH

see Figure 7.3 for recommended actions.

Temperature Monitoring-Cooldown

During cooldown temperature differentials should be maintained within the limits specified over.

ITEM	SECTOR	SENSORS	DIFFERENTIAL	ACTION
Coil Shell	I/P to O/P	7 w 8*(1)	50 K	Hold Coil
Coil	Bottom to	1w2*, 4w3, 5w6*	30 K	Hold

Shell	Top	22w21*, 23w24, 26w25*		Coil
Coil Shell	End to End	1 to 4w 23 to 26*	30 K	Hold Coil
Radscreen	I/P to O/P	9w10*	30 K	Hold Radscreen
Radscreen Inner	Bottom to Top	11w12, 12w13	15 K	Hold Radscreen
Radscreen outer	Inter Quadrant	29w30*, 30w31 31w32, 29w32	10 K	Hold Radscreen

(1) 7w8 indicates sensor 7 should be compared with sensor 8.

Load Monitoring

The following alarm levels have been set on the load monitor

	TENSION	COMPRESSION
HIGH	2500	500
SHUTDOWN	3000	1000

Helium Level

The trip levels on the two relays have been set at the following levels. Hysteresis on both relays set to zero.

RELAY 1	SHUTDOWN	10%
RELAY 2	LOW LEVEL	20%

Helium Pressure

The microswitches have been set to trip at the following pressures

SWITCH 1	HIGH	0.4 bar gauge
SWITCH 2	SHUTDOWN	0.7 bar gauge

7.6 SENSOR POSITIONS

The temperature sensors positions are defined schematically on AJE 1005 sheet 2 and in Figure 7.4 of this manual and physically in the following drawings:

Coil Shell	AJE 0092
Outer Radscreen	AJE 0075
Inner Radscreen	AJE 0076
Current Leads	AJE 0175
Neck instrumentation	AJE 0174

Sensors on the coil shell (TS1 TO TS6 and TS21 TO TS26) are bonded in blind holes. Sensors on the sorbs (TS33 and TS34) are bonded in blocks which are in turn attached by screws to the sorb baseplate.

Sensors on the Inner Radscreen (TS12 and TS13) are bonded in blocks which are screwed to the outside of the inner skin of the radscreen.

Sensors on the Outer Radscreen (TS 29 to 32) are bonded in blocks which are in turn screwed to the outer skin of the radscreen.

Sensors on the Nitrogen pipe TS 9, 10 and 11 and AST1a and AST2 are attached to the pipes using aluminium tape and a thermally conductive compound.

Sensors in the Helium Return Pipe TS7, 8, 27 and 28 and CU1 and CU2 are bonded in blind holes.

Sensor on the Helium Return Pipe AST4 is attached using aluminium tape and a thermally conductive compound.

7.7 HELIUM PRESSURE

The dewar is fitted with the following electrically actuating pressure devices attached via a T to the dewar gas recovery ring.

a) Two-limit pressure switch ASCO type PCIOA REIOAII. The switch has two individually settable limit switches which are set to give "High" and "Shutdown" warnings respectively. The single pole changeover contacts from the switches are brought back to the CLSCC - see drawing AJE 1005 sheets 1 and 2. The limits are spanner adjustable after removing the cover and visual indication of setpoint is provided in bar gauge.

Switch Rating	5 A 125V AC
Adjustable Operating Range	0.4 to 5 bar gauge
Fixed Deadband	85 mbar
Maximum Sustained Pressure	10 bar

b) Pressure transducer SETRA Type 205-2. The Setra pressure transducer (Cornell supplied) is supplied with shielded cable attached for connection to Cornells' instrumentation system.

8 VACUUM SYSTEM

8.1 Description

The outer vessel of the magnet, in conjunction with the services turret, neck tube and helium dewar outer space form one complete vacuum system. This system provides the essential insulation around the magnet and services before being cooled to working temperature.

On the side of the service turret is a large (6") gate valve which is the attachment port for fitting a high vacuum pump eg turbo-molecular. The system is shown in Figure 8.1.

The vacuum system, including the turbomolecular pump, should be kept in operation until the coil has been cooled down to a temperature of about 30 K. Below this temperature the high vacuum gate valve can be closed and the system shut down if the vacuum level is maintaining 10^{-6} to 10^{-5} mbar. If the coil or the radiation screen is warmed up either intentionally or accidently this will cause a rise in pressure in the cryostat and the vacuum system must be brought back into operation. Only when the vacuum level as measured at the pump is adequate - namely, better than the system vacuum level - can the H.V. gate valve be opened, and the cryostat pumped down.

It is good practice to occasionally regenerate the sorbs by bringing the turbo pump into operation, opening the gate valve and heating the sorbs very slowly to the temperatures indicated in section 8.3.2.

Measurement of the vacuum is made by transducers, supplied by Cornell, mounted in the instrumentation cabinet. This cabinet also contains a gas admission valve.

Protection against overpressure in the system is by a bursting disc mounted on the current lead stack. The disc holder is spring loaded so that some pressure relief occurs at typically 2 psi differential before the disc fails at 5 psi differential. For details of replacement discs - see section 8.4.

Note - It is most important that whatever pumping system is used, no contamination of the vacuum space should occur. In the event of mains *failure, all vacuum valves should be closed promptly.*

8.2 Valves, Gauges, etc

8.2.1 Gate Valve - the operation of the gate valve is by hand lever. Under normal vacuum conditions this can remain shut with the outlet side under high vacuum conditions and with the turbo pump fitted and valved off. It is essential that the valve remains shut unless the turbopump is fully operational.

8.2.2 Shut off Valve - instrumentation cabinet. This is a bellows sealed right angle valve (NW 25). It is essential to shut this if any vacuum measuring head needs to be removed.

8.2.3 Gas Admission Valve - instrumentation cabinet. Bellows sealed. Right angle valve. This incorporates a flow restrictor to prevent the inrush of gas displacing any superinsulation within the vacuum space. The filling time is designed to be about 10 hours.

To assist in subsequent pumping down and to avoid contamination with water vapour etc, the admittance gas should always be dry nitrogen. The connection to this valve is NW 10.

8.2.4 Other entries - there is a spare pumping port on the lower side of the magnet vessel. Normally this will be concealed within the magnet yoke and is covered by a bolted on plate with 'O' ring. This plate must not be tampered with, unless the magent is at atmospheric pressure.

8.2.5 Gauges and read-out units- these are supplied by Cornell. The entry to the vacuum system for this purpose are 1 off NW 25 and 1 off NW 10.

8.3 Adsorption Pump

8.3.1 Description

The sorbs are provided to pump any helium in the cryostat volume which will not cryopump onto the surface of the coil and, as far as possible, to preferentially pump any contaminants which would otherwise be cryopumped by the coil. There are two sorbs, one at top dead centre and the other at bottom dead centre on the outside diameter of the coil and each is supported by GRP beams which hold it away from the coil. These provide thermal isolation of the sorbs in the event of temperature transients on the coil eg a quench, so that the sorb does not outgas during the typical 90 second duration of a quench when there could be a moderate voltage on the coil.

Each sorb contains 150 cc of charcoal, two 10 watt 330 Ω heaters and a rhodium iron sensor which is monitored by the Doric data logger. Two heaters, one on each sorb, are wired in series (see AJE1005) so as to provide redundancy if a heater fails, but still minimising the number of wires to ambient. Each heater circuit requires a 120 V variable AC supply. Because of the thermal isolation of the sorb from the coil, caution must be exercised when using the heaters to prevent overheating of the sorb. The maximum heating is therefore 20 W for 50 minutes which will raise the sorb from room temperature to about 100°C. At low temperatures much less energy will be needed to outgas the sorbs. To guard against overheating, the data logger alarms on the temperature sensors should be used to open the contacts on the heater circuits when the temperature reaches 100°C.

The cooldown of the sorbs will be very slow taking of the order of days before the pumping action for helium gas becomes effective.

8.3.2 Operation

The sorbs must only be baked when the cryostat is still being pumped and the vacuum level is about 10^{-4} mbar or better. After airing up the cryostat the baking temperatures are as follows:

$R = \frac{V^2}{P}$ $660\Omega = \frac{V^2}{20W} = 114V$

MAX. VARIAC SETTING 95%
FOR A MAXIMUM OF 50 MIN.

Coil Temperature	Baking Temperature	
Room temperature	373K	)
60K	200K	) Recommended
15K	70K	)

4K	15K	) Optional

Whilst pumping the cryostat and with the coil at helium temperature, periodic baking of the sorb at 15 K is recommended to drive off helium and reactivate the charcoal.

Maximum Temperature of the sorb	100°C (373K)
Maximum Power per sorb	20W for 50 mins

8.4 Vacuum system - general data

Manufacture code BS 5500

Volume of whole vacuum system:- 10 m^3

Required vacuum level prior to cooldown: better than 10^{-3} mbar for 36 hours.

Maximum initial pump-down rate allowed 300 mbar/hour

HV Pumping port size DN160 ISO

Gas admittance valve port NW 10

Gas admittance orifice 1.5 mm diameter

Transducer mounting ports 1 off NW 10
1 off NW 25

Maximum allowed differential pressures

a) full internal vacuum

b) positive internal pressure, 0.5 bar

Bursting disc failure pressure 0.3 bar (5 psi)

Bursting disc details: 200 mm dia Aluminium, nominally 0.009 ins
Type NR, Flat with cruxiform groove.
5 psi burst pressure - reference NG7955
Marston Palmer Ltd
Wolverhampton, UK
(0902-783361)

10 ROUTINE MAINTENANCE, ASSEMBLY, DISASSEMBLY, AND DOCUMENTATION

10.1 Maintenance - Coil Warm

Items that can be attended to when the coil is warm are as follows:

10.1.1 Suspension Jacks (16 off)

These have been greased on assembly. However, when accessible, inject a small quantity of Texaco Multifak EPO or EPC grease, into the Grease nipple on each jack. Use only a low pressure hand gun and use only one stroke. Do not overfill or use power equipment.

10.1.2 Bursting Disc on vacuum space

If this requires changing, remove 8 off cap head screws holding burst disc assembly. (See Fig. 10.1) Disassemble parts, clean thoroughly, apply thin coat of vacuum grease to O rings, fit new disc and re-assemble.

10.1.3 Bursting Disc on Dewar

\- This is mounted in a large hexagonal housing at the top of the dewar near to the pressure gauge. New discs are obtainable from Elfab Huges via Wessington Cryogenics Ltd (091 - 4165444).

10.1.4 Battig Valves on Dewar:

The valve seats can be renewed whilst the coil is cold but non-operational, provided cryogenic cleanliness is observed. The details are given in section 4.2 above.

10.2 Maintenance - Coil Cold

The operations required at this stage are to monitor and record:

a) vacuum level.
b) suspension loads.
c) coil position settings
d) coil current and voltages
e) coil lead gas flow and temperatures
f) radiation screen temperatures, supply and flow rate

If any readings show a significant change, Oxford Instruments should be informed prior to any further investigation.

10.3 General Notes on Disassembly of CLEO II

Cornell should note that during the guarantee period, no work or modifications should be done on the magnet without Oxford's permission. These notes are thus intended for Cornell's guidance beyond the guarantee period.

10.3.1 The helium and nitrogen circuits for coil and radiation screen take the form of fully welded pipe systems. Any dissembly involving moving the helium dewar will necessitate cutting and subsequent rewelding of these pipes. Due to the confined space for this work, automatic orbital welding equipment was used in the installation and could be necessary in any rebuilding.

10.3.2 The coil, weighing 7.5 tonnes, is suspended inside the outer case by radial and axial suspension rods. These have been designed for "3G" maximum load and it is essential that the magnet is properly supported at all times. For example:- if a yoke collar is to be moved away from the magnet, then the vacuum casing must be supported under the transport support faces on each side, so that the weight is taken off the coil collar support brackets. Care must be taken that external loads are not applied to the bodies of the suspension jacks - 16 off - projecting from 8 pockets around each end of the outer casing. This especially applies to the underneath ones. Do not attempt to support the magnet vacuum casing in this region. Unless the axial supports are attached, to the iron yoke, the 4 axial transit brackets <u>must</u> be attached to the magnet at all times.

10.3.3 The various covers on the dewar, current lead stack and magnet body usually communicate with the main vacuum space. Therefore none should be removed or tampered with when the magnet is below 290°K or under vacuum, as there is a high probability of damage to the system if there is a sudden release of vacuum.

10.3.4 Cleanliness is essential when working on cryogenic systems. Keep any holes into the system covered over whenever possible.

10.4 Disassembly sequence

Assuming the magnet is inside the iron yoke and is already at ambient temperature and pressure, the basic sequence of disassembly would be as follows:-

a) Disconnect all services, cables, pipes etc.

b) Remove instrumentation cabinet, burst disc holder and gate valve with appropriate flanges - tape over and cover flanges on current lead stack (CLS).

c) Ensure the neck assembly jig is supporting the neck tube. Undo and lower the sleeve joint below the CLS. After removing superinsulation the final pipe and conductor joints can be seen. Consult with OI about the method of disassembly. It is necessary to plan where to cut pipes to enable them to be re-welded conveniently. A temperature controlled electrical heater is useful to undo and remake the soldered conductor joints to the leads.

d) Disconnect instrumentation cable plugs.

e) After tightening the three transit stops, lift dewar/CLS assembly clear of the iron yoke. Lift weight is 1 tonne.

f) The dewar and current lead assembly should if possible be kept as a single unit but if separation is needed, consult OI as it is critical where pipes are cut to enable reconnection.

g) Once the dewar is removed, the iron yoke can be removed leaving in position the coil collars. After recording the counter readings, remove the jack operating shafts and load cell units before moving away the east coil collar, supporting the vacuum casing as per paragraph 10.3.2 above. Attach the axial transit brackets and lift the magnet via 4 lifting lugs and place on the transportation frame.

h) Either end plate of the vacuum casing can be removed from the magnet provided the other end plate is left bolted in place.

First remove the dowels in the end plate by using hydraulic injection. On the east end the 4 sleeves surrounding the axial restraints must be unscrewed first to allow the end plate to be removed. Cover the bellows with protective tubes to prevent damage before removing the end plate off. Use the end plate lifters supplied to take the weight - ½ ton per plate.

10.4 Documentation

10.4.1 Drawings Supplied

Number	Title	Sheets and Issue
AJE 310	Arrangement drawing of Cleo II	1A 2A
AJE 300	Axial section through cryostat	1B
AJE 301	Radial section through cryostat	1A
AJE 302	Shipping and installation layout	1C 2C
AJE 303	Contraction Allowances	1C
AJE 304	Yoke drilling/tapping requirements	1B
AJE 023	Coil shell end flange insulation	1A
BJE 024	Inner ring segments, peg and sleeve	1A
AJE 047	Vacuum vessel transport frame	1B
AJE 060	G A vacuum vessel	1D
AJE 061	Outer shell fabrication	1F 2F 3F
AJE 062	Inner shell	1D
AJE 063	End Plate	1F 2E
BJE 064	Blanking plate	1A
BJE 065	O rings	1A
BJE 066	Dowels	1A
BJE 067	Special washers	1A
AJE068	Transport cradle (LoE to Lo)	1A
AJE 069	Vacuum vessel support structure	1C
AJE 070	Radiation screen assembly	1D 2D 3D
AJE 071	Outer panel details	1D 2D 3D
AJE 072	Inner panel details	1C 2C 3C
AJE 073	End plate details	1C 2C
AJE 074	Attachment details	1C
AJE 075	Instrumentation outer radscreen	1A
AJE 076	Instrumentation inner radscreen	1A
AJE 081	Coil shell fabrication	1D

AJE 082	Coil shell machined details	1D 2D 3D
AJE 083	Coil shell end flange	1A
BJE 084	Conductor clamps axial	1B
BJE 085	Radial support bracket	1A
BJE 086	Axial support bracket	1A
AJE 088	Coil assembly	1C 2C 3C 4C 5D 6C
AJE 089	Conductor clamps	1A
AJE 090	Support system - radial	1B
AJE 091	Support system - axial	1A 2A
AJE 092	Instrumentation coil shell	1A
BJE 100	Radial support rod	1A
BJE 101	Axial coil support rod	1A
BJE 102	Heat sink clamps	1A
BJE 103	Heat sink bases	1A
BJE 104	Axial support details	1A
BJE 105	Radial support rod clevis	1A
BJE 106	Radial support sealing plate	1D
BJE 107	Axial support details	1A
BJE 108	Axial support clamp ring	1A
BJE 109	Clevis pins	1A
BJE 110	Modified screw jack details	1A 2A
BJE 111	Radscreen suspension details	1A
BJE 112	Flexible bellows	1A
BJE 113	Axial support transport details	1A
BJE 114	Accessories	1A
AJE 115	Radial support details	1C
BJE 116	Braided lead	1A
BJE 117	Axial support details	1A
BJE 118	Axial support details	1A 2A
BJE 119	Support plate jacks	1A
AJE 0128	Battig valve open limit	1A
AJE 0129	Service turret assembly	1M 2L 3L4M 5L 6L s 7L 8L
AJE 130	Current stack assembly	1E
BJE 131	Current stack tufnol tube	1B
AJE 132	Current stack OVC	1H
BJE 133	Special socket weld fittings	1E
BJE 134	Ceramic feed thro assembly	1D 2D
BJE 135	Helium reservoir GRP plate	1B
BJE 136	Current lead entry plate	1B

AJE 138	Stand for electrical cabinet	1A
AJE 139	Sensor cable layout	1A 2A
AJE 141	Interface dewar/current lead stack	1B
AJE 142	Neck assembly	1E 2E 3E 4D
AJE 144	Braided lead assembly	1B
AJE 145	Electrical cabinet	1D 2D 3B
AJE 146	Vacuum insulated transfer line	1D
AJE 151	Dewar	1 to 5 Rev 2 6 Rev 0
AJE 152	Service Arrangement	1B
AJE 153	Al/st transition joint	1B
BJE 154	Rh/Fe sensor clamps	1A
AJE 155	Neck Assy superconductor loop	1B
AJE 156	Bent tubes for neck assembly	1B
AJE 157	Kabelmetal bayonet	1B
AJE 158	Sleeve, 19 mm	1A
AJE 159	Support plate for service turret	1A
BJE 160	Branch pipe	1A
BJE 161	Sash rod	1A
BJE 162	Coil details	1B
BJE 163	Hose Assembly	1B
BJE 164	Pipe fittings for cooling system	1A
BJE 165	Coil hose clip fittings	1A
BJE 168	Sorb for coil shell	1A
BJE 169/1	Conductor loop support	1A
AJE 173	Neck support jig	1A
AJE 174	Neck instrumentation	1A
AJE 175	Service turret instrumentation	1A
AJE 184	Welded assembly of neck tube	1A
AJE 1005	Wiring diagram for CLEO	1D 2C 3C
BJE 1006	Radiation screen cooling system	1A

10.4.2 <u>Figures attached</u>

General Arrangement of CLEO II

3.1 Radscreen controller flow diagram
4.1 Valve in helium dewar
5.1 Current leads
5.2 Current lead operating characteristic

10.4.3 Proprietary manuals (supplied separately)

Temperature Monitoring

Digitrend 245	Operating manual
Digitrend 245	Maintenance manual

Cryogenic Calibration Rh/Fe characteristic

Radiation Screen Control

West	2072	Controller User Manual
West	2050	Controller Installation and Operating Instructions

Controller Circuit Diagram SIGMA drawing number C1401

Mixer arrangement	AS	drawing number radscreen mixer
Mixer exchanger	AS	drawing number AI0833
Mixing chamber	AS	drawing number AI0954

Load Monitoring

AJB Association 'Fylde 20 Channel Load Cell Monitor' handbook.

Helium Level

Liquid Helium Level Meter - Instruction Manual.

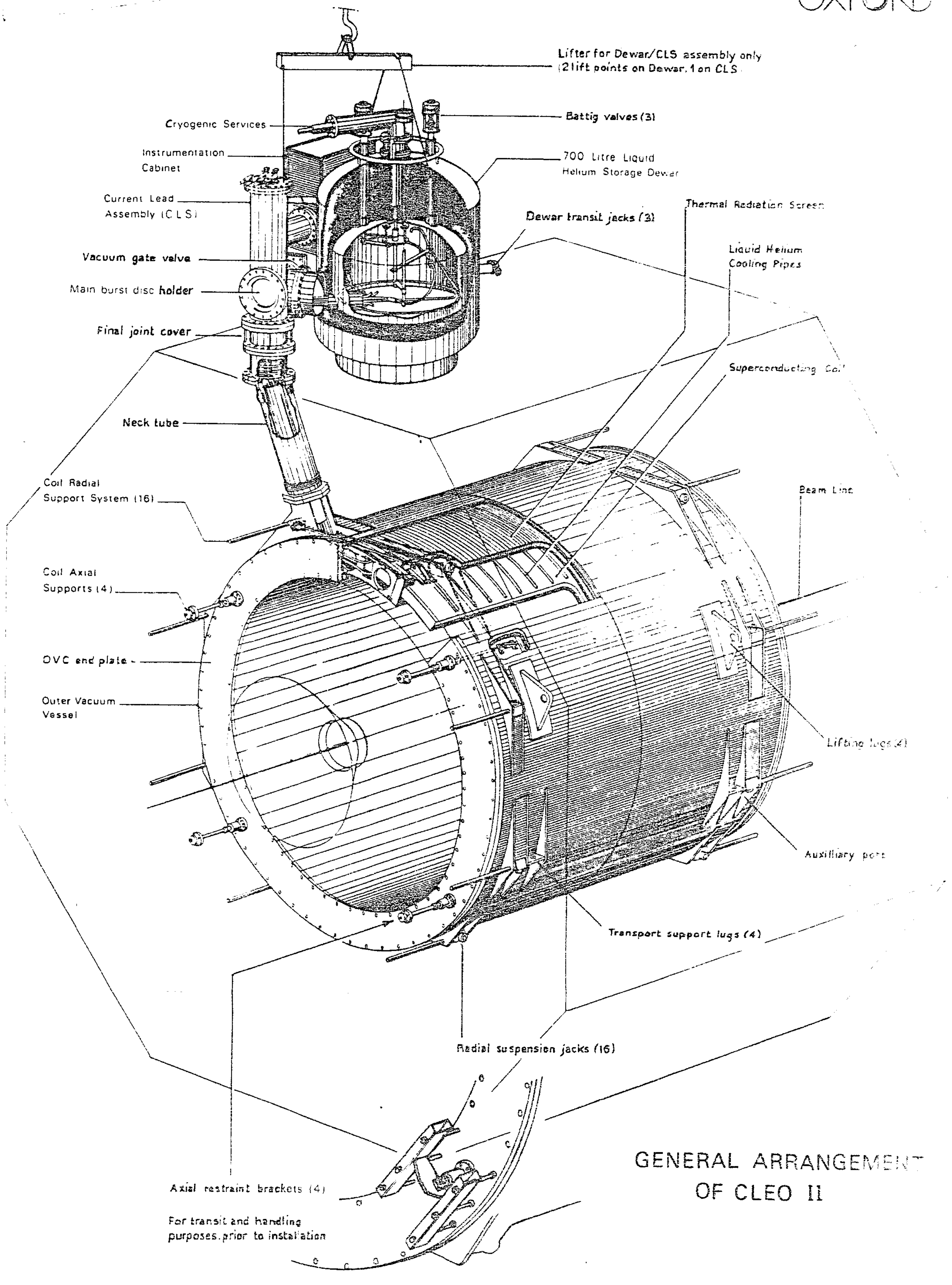
Current Lead Control

Eurotherm 810 Controller (Gas Flow Control)
Landis and Gyr Valve Actuator (Gas Flow Control)
Platon PR Type Floscan Circuit Diagram (Gas Flow Monitor)
Omron E5E3 Controller (Heater Controller)

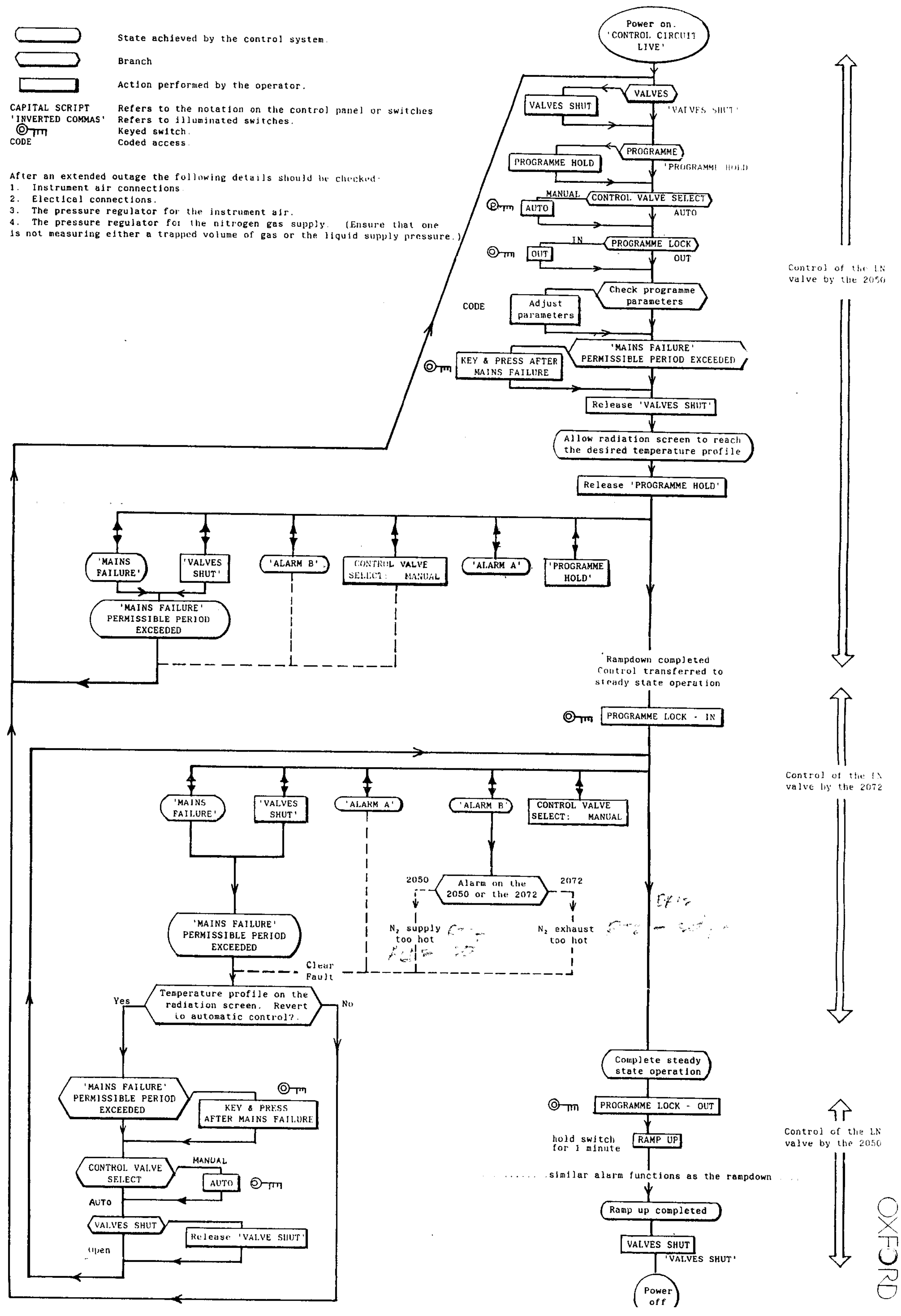
Helium Dewar Valves

Helium Dewar Battig Valve Actuator.

OXFORD



GENERAL ARRANGEMENT
OF CLEO II



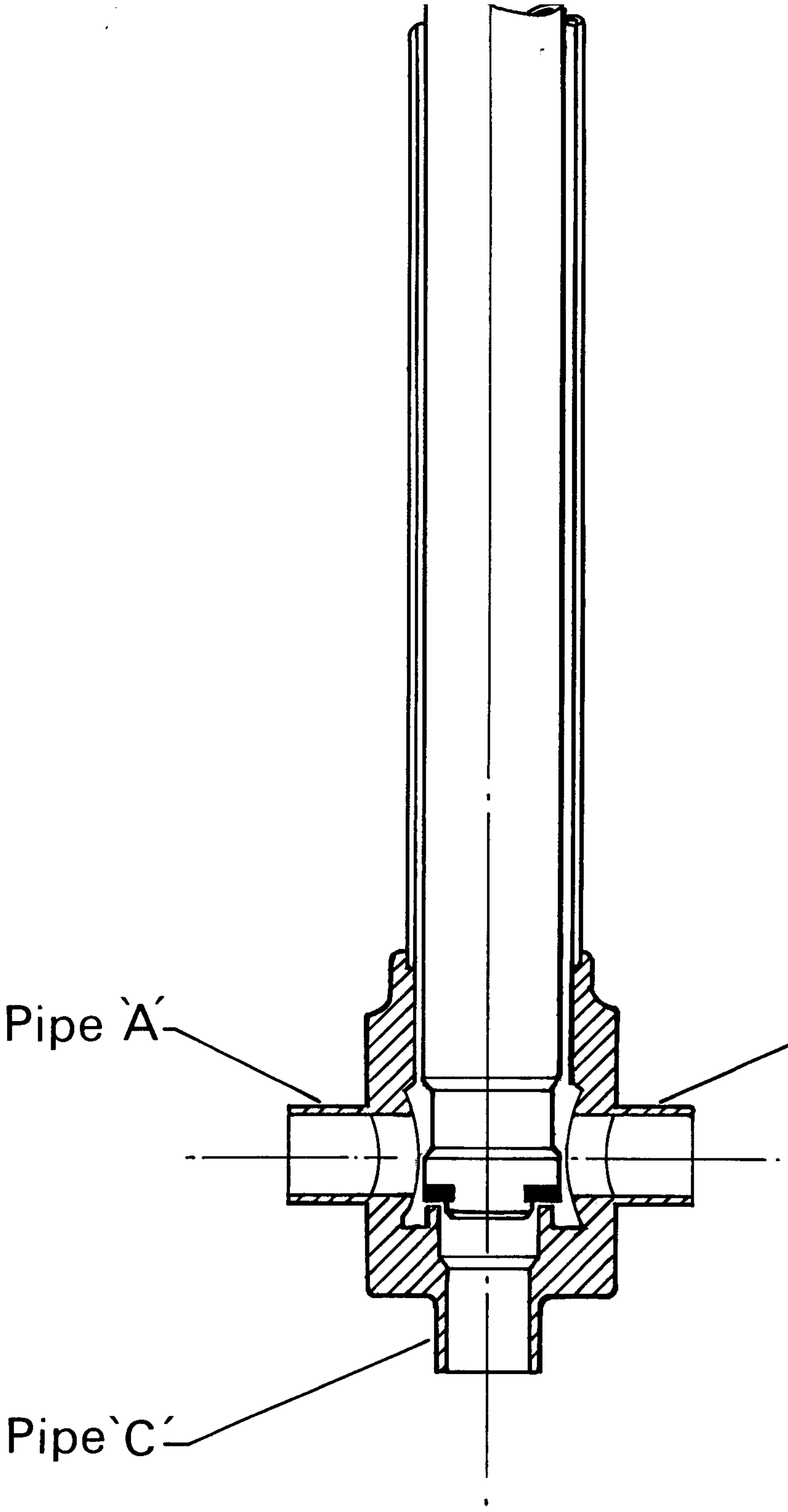
After an extended outage the following details should be checked:-

1. Instrument air connections.
2. Electical connections.
3. The pressure regulator for the instrument air.
4. The pressure regulator for the nitrogen gas supply. (Ensure that one is not measuring either a trapped volume of gas or the liquid supply pressure.)

RAD. SCREEN CONTROLLER FLOW DIAGRAM

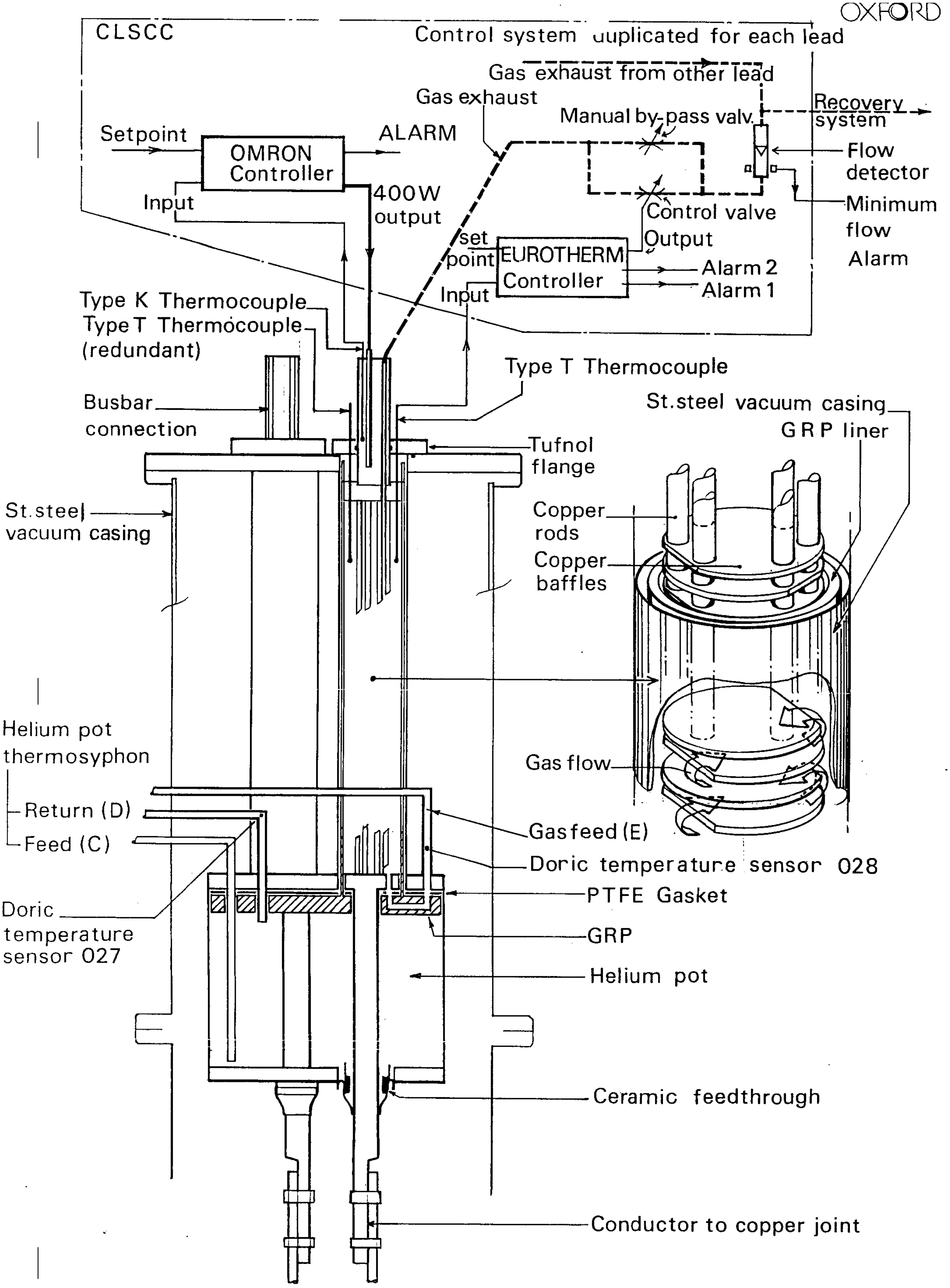
Fig. 3.1

OXFORD



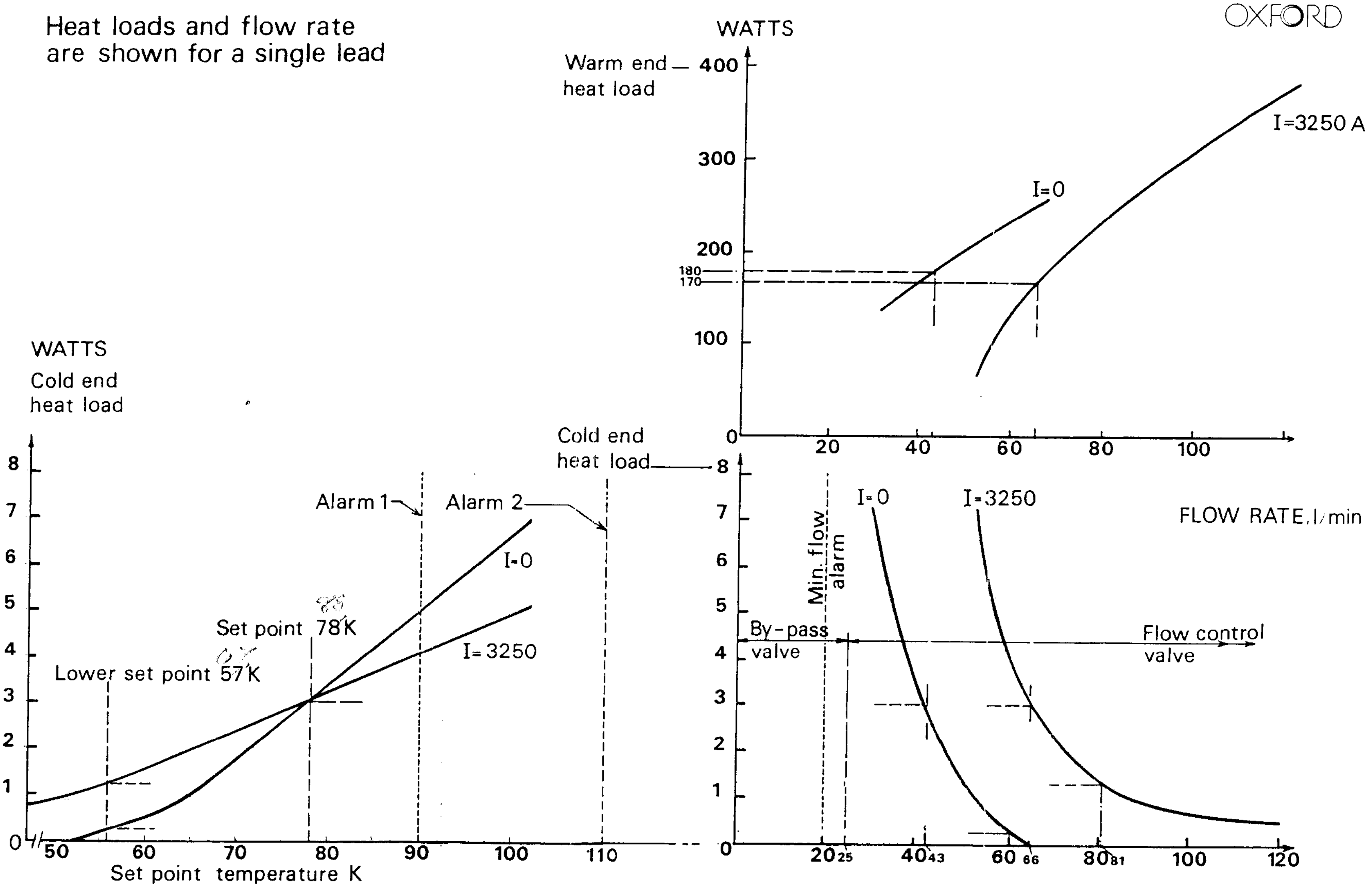
Flow diverter valve
size 12/15 NP 10 type BC

VALVE IN HELIUM DEWAR	Fig 4.1



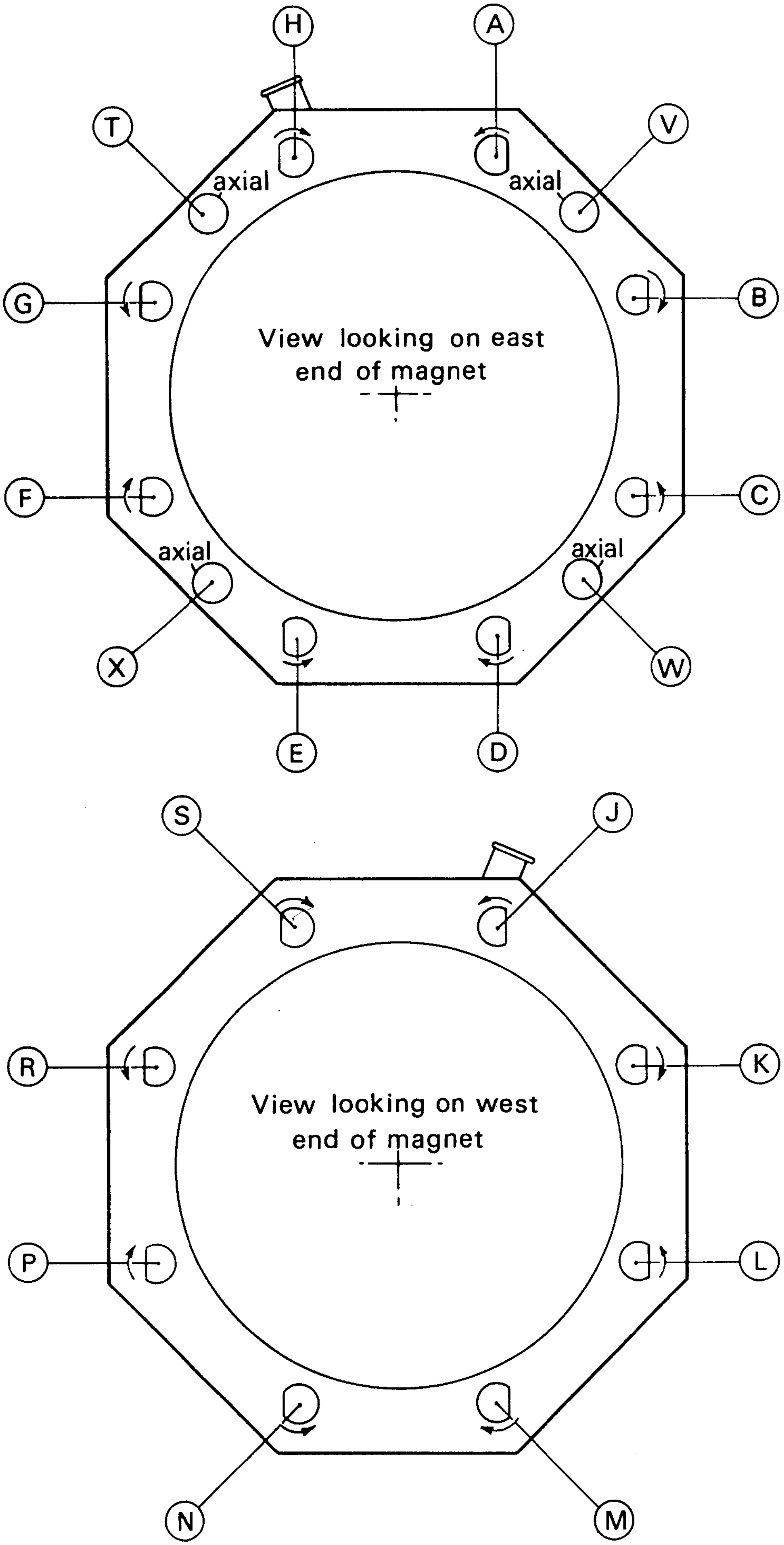
CURRENT LEADS

Fig. 5.1


Heat loads and flow rate are shown for a single lead

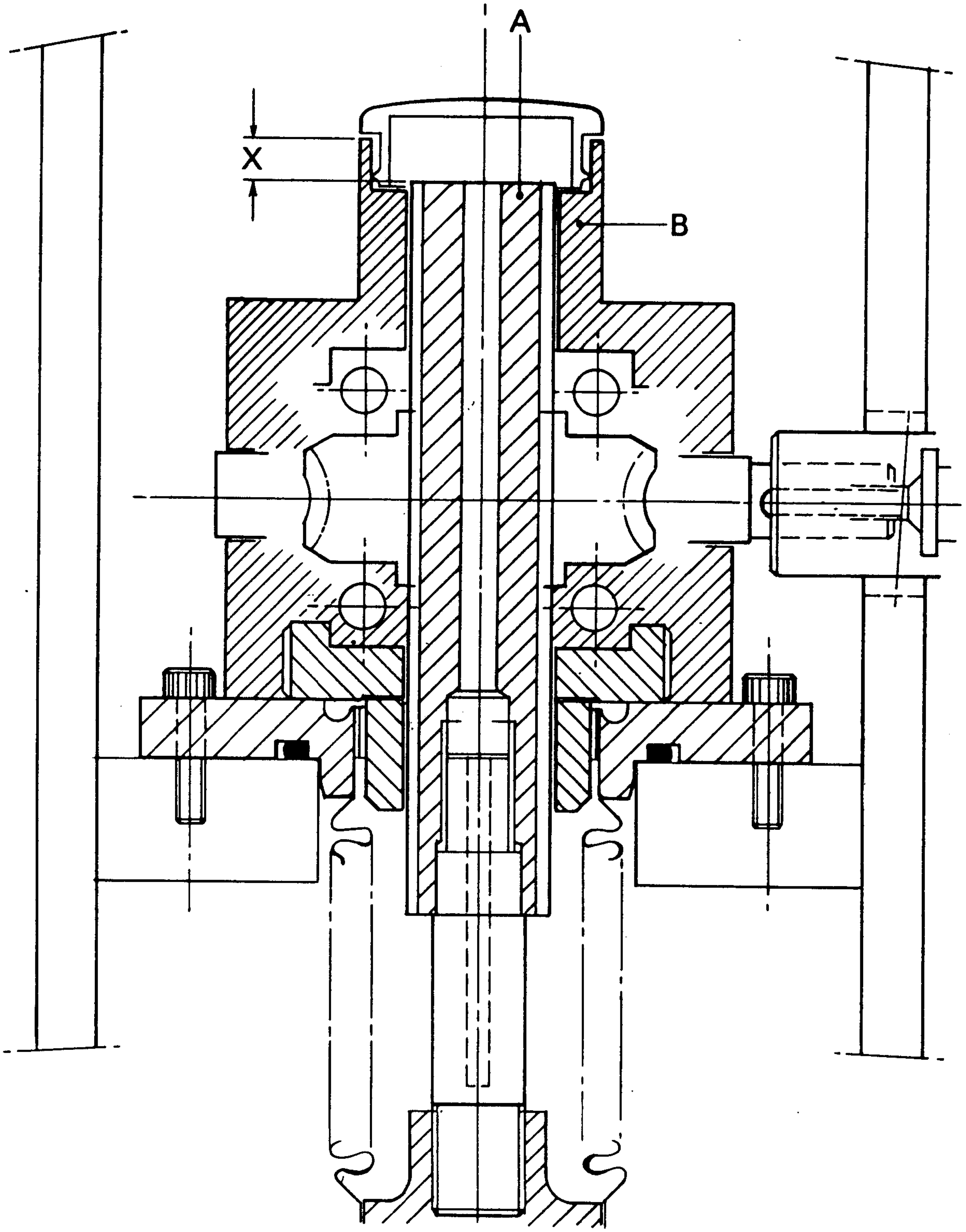
CURRENT LEAD OPERATING CHARACTERISTICS

Fig. 5.2



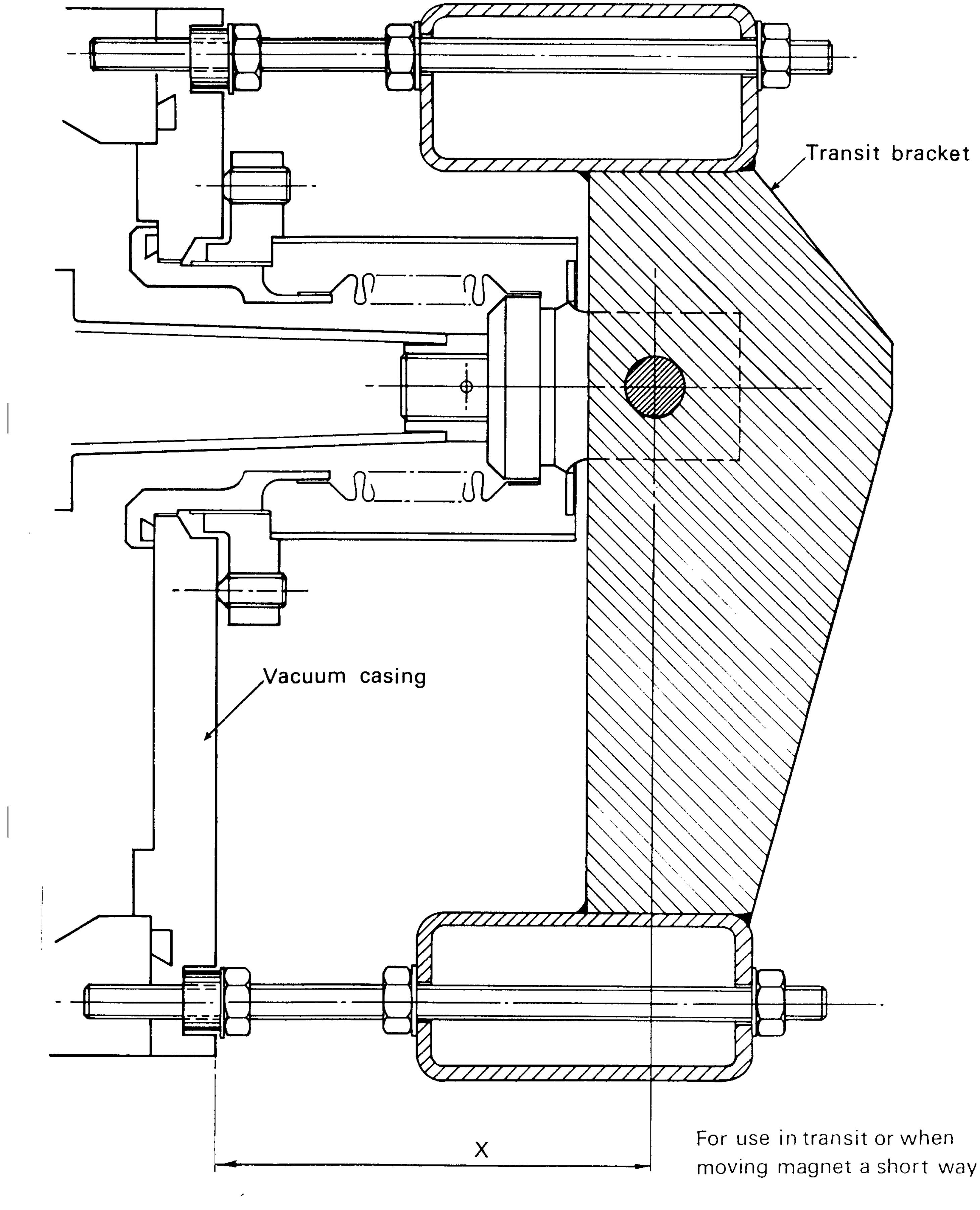
LOCATION of RADIAL & AXIAL SUPPORTS

Fig.6.1



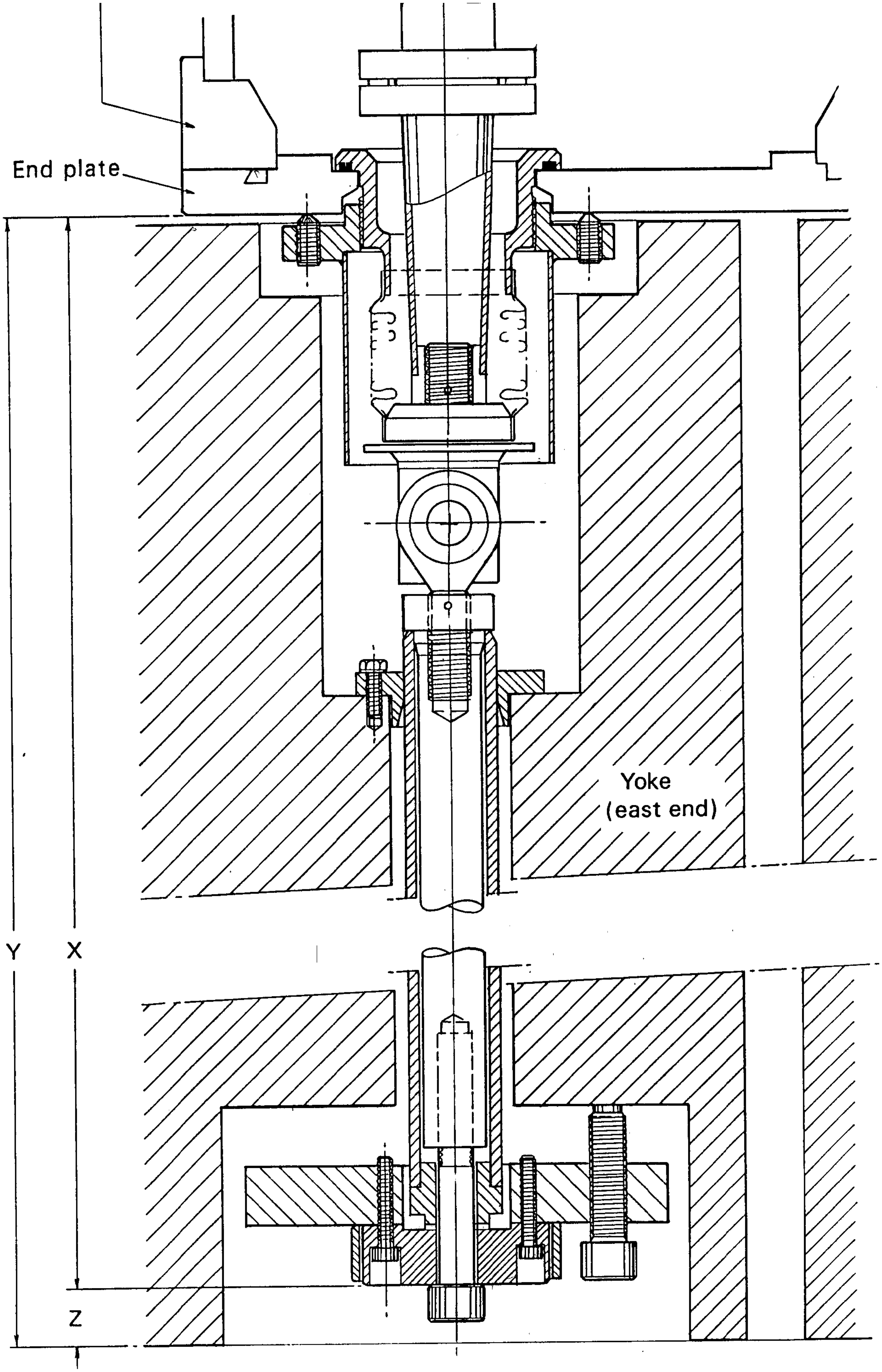
RADIAL SUPPORT JACK UNIT SHOWING DATUM READING 'X'

Fig. 6.2



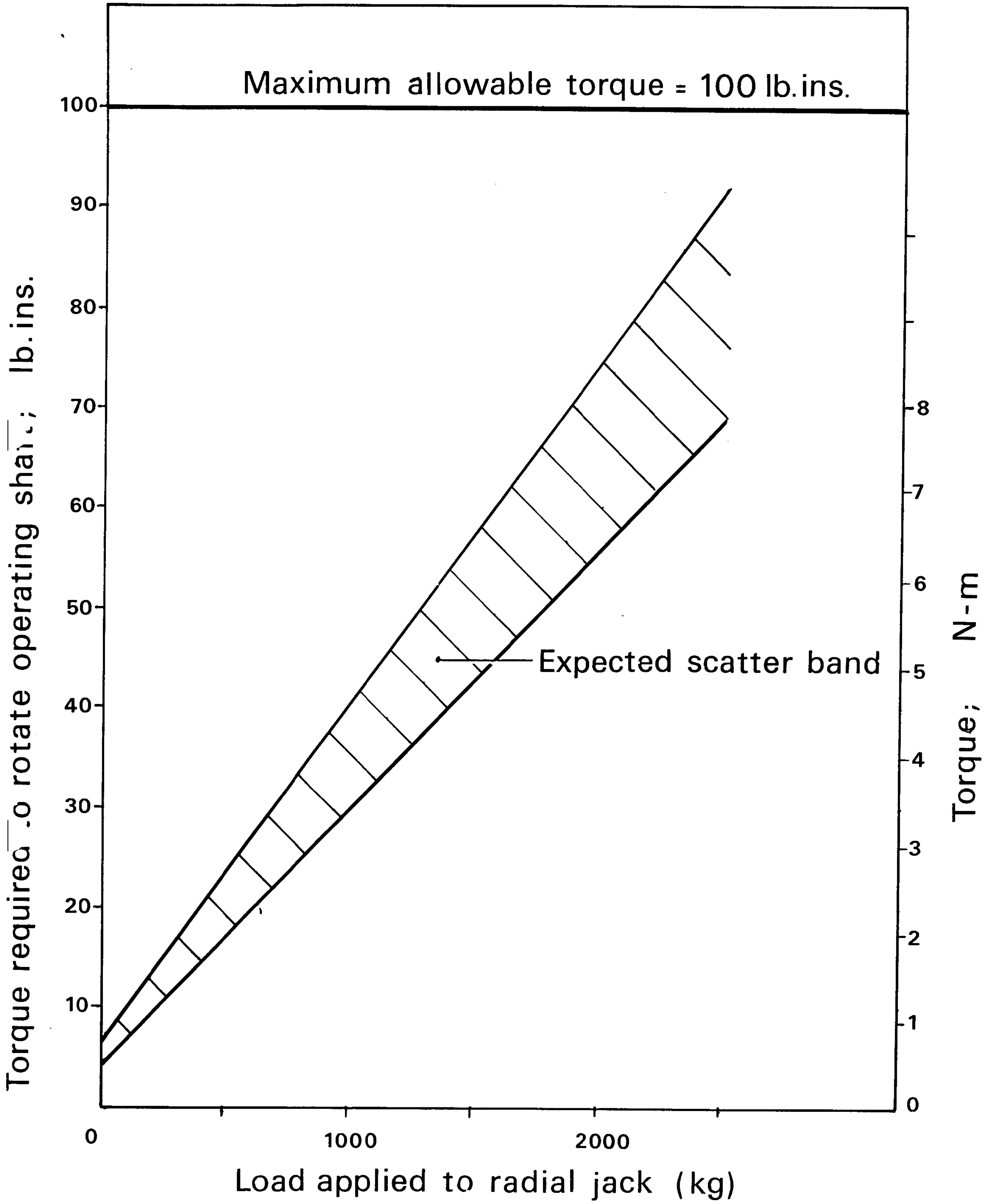
For use in transit or when moving magnet a short way

TRANSIT BRACKET SETTING DIMENSIONS | Fig.6.3

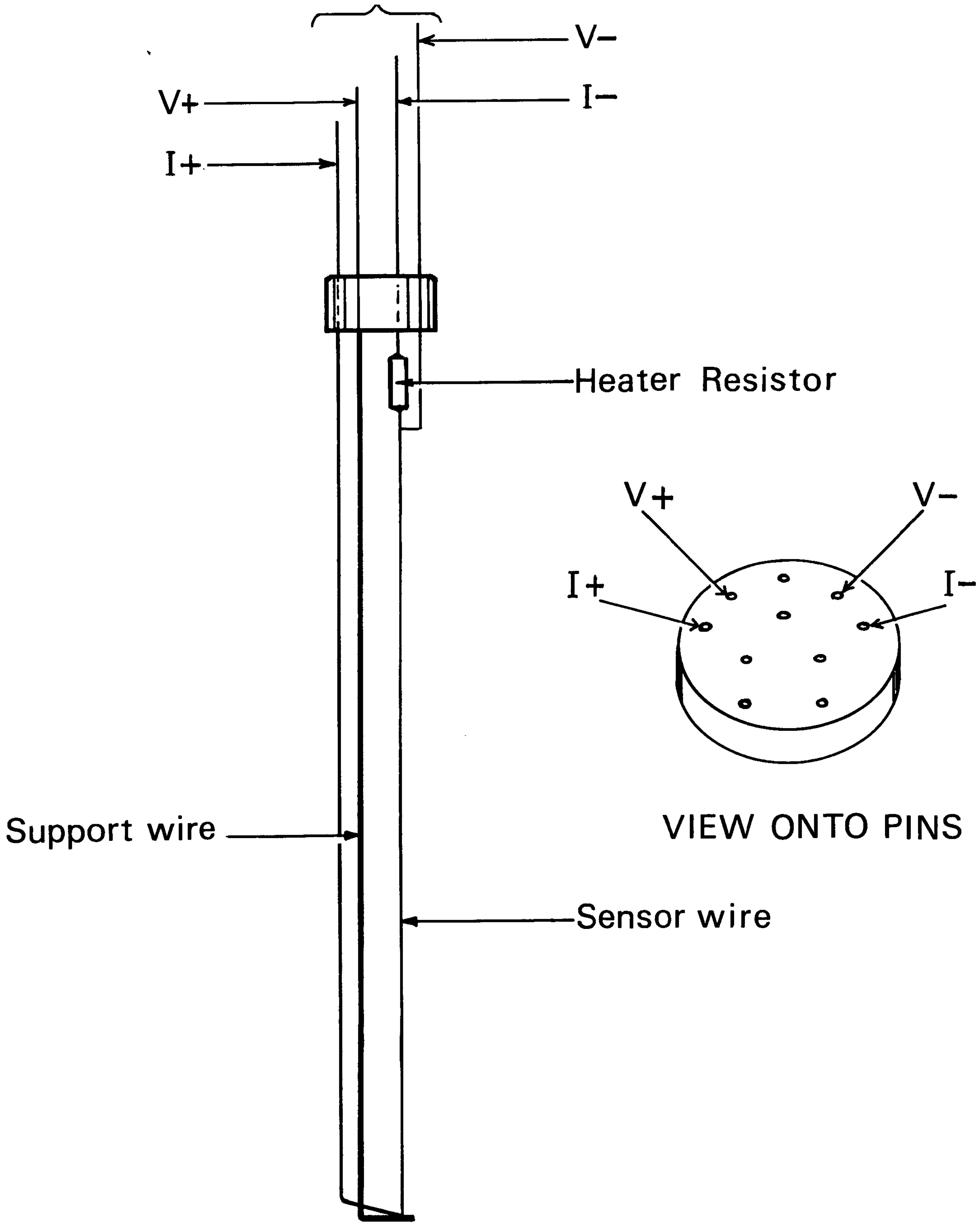


AXIAL SUPPORT EXTENSION ROD SHOWING DATUM READING `X'

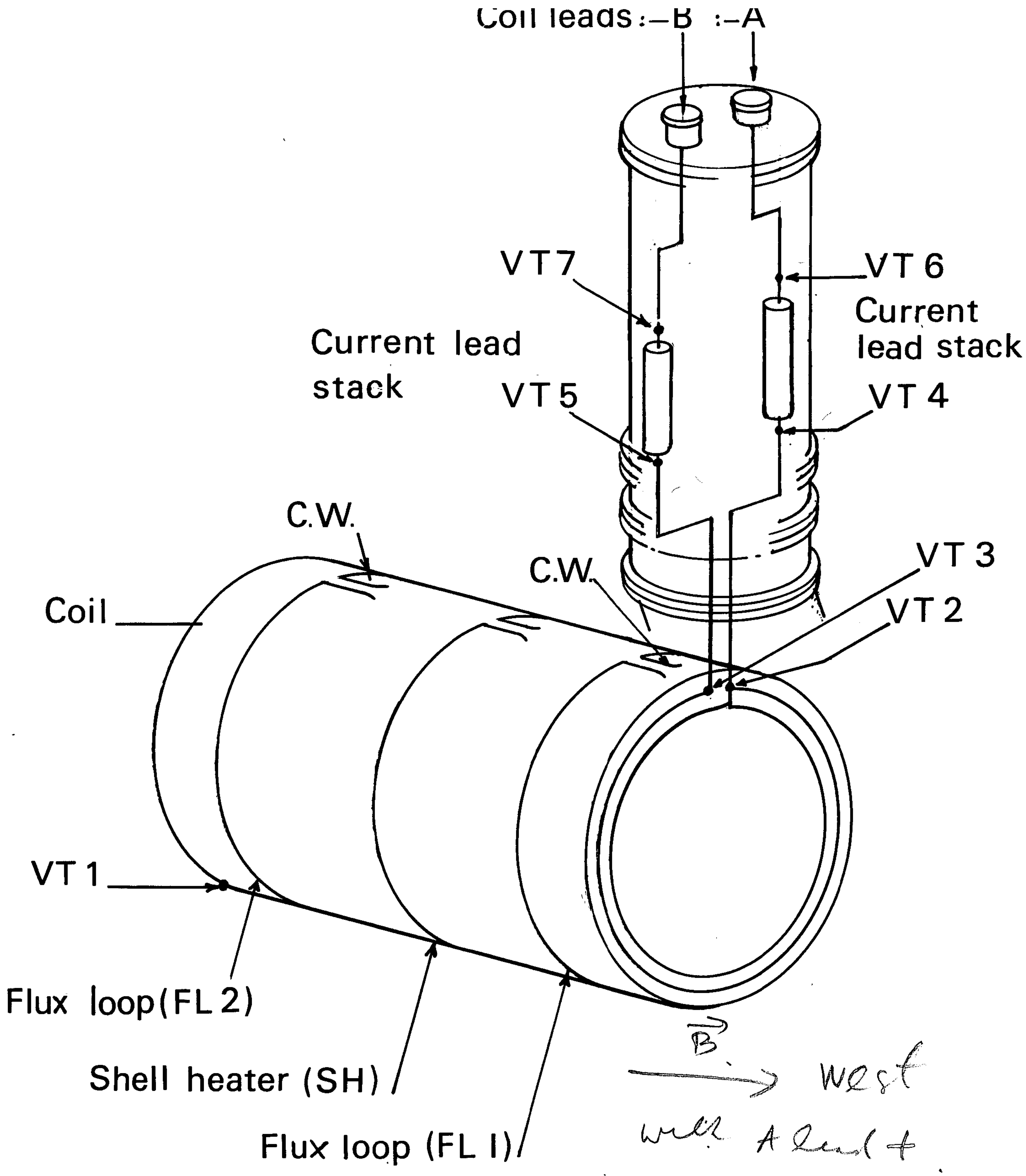
Fig. 6.4



TORQUE vs. LOAD FOR RADIAL JACKS | Fig. 6-5



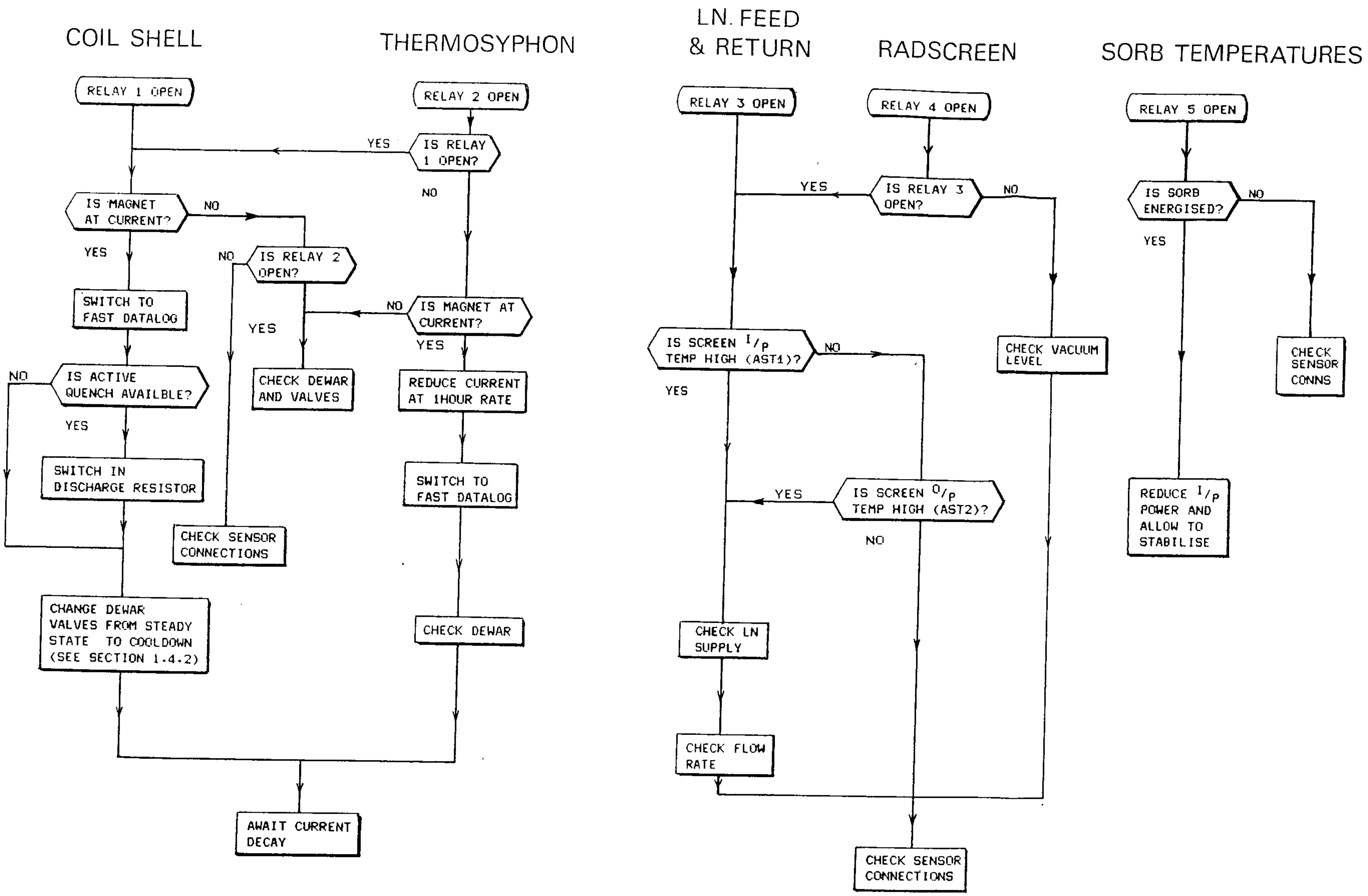
He. PROBE (DIAGRAMATIC) Fig. 7.1



$\vec{B}$ ⟶ west

with A lead +

VOLTAGE TAPS and FLUX LOOPS | Fig. 7.2



STEADY STATE TEMPERATURE ALARMS

Fig. 7.3