Secty. Reactor Safety Committee
16/4/68

AAEC/M4

~~40~~

50

AAEC/M4

AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

REACTOR HIFAR

THE CONTROL REVERSAL CIRCUITS

by

G. PAGE

Issued October 1967

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

REACTOR HIFAR

THE CONTROL REVERSAL CIRCUITS

by

G. PAGE

ABSTRACT

This manual describes in detail the operation of the CONTROL REVERSAL circuits in HIFAR and their relation to other parts of the safety circuits.

<u>CONTENTS</u>

1. INTRODUCTION

This manual must be read in conjunction with Manual M1, 'Introduction to HIFAR Guard and Safety Circuits'. It is part of a series of manuals on the instrumentation of the reactor HIFAR. (See Appendix 1.)

2. THE CONTROL REVERSAL CIRCUITS

When the CONTROL REVERSAL condition is initiated, the following safety measures are brought into action:

(a) The six control arms are driven at full speed into the core. They take approximately 5.0 minutes to travel the full 56°.

(b) When any one of the six control arms reaches and operates its bottom limit switch and the Main Control Switch is turned OFF, then the RESTRICTED TRIP condition is initiated, that is all six holding magnets are released and the Fine Control Rod is driven in fast. This means that the remaining five arms will drop freely into the core under gravity if they are not already fully in the core.

2.1 Conditions Initiating a CONTROL REVERSAL

The CONTROL REVERSAL condition is an automatic power reduction of the reactor and it is essentially the same condition as that initated manually by operation of the Fast Down switch in Control Room Panel No. 5. The conditions which can initiate a CONTROL REVERSAL are as follows:

(a) Operation of the Up-limit switches in the heads of one or more of the Control Arms.

(b) Opening of either door to the D_2O Plant Room.

(c) Reactor Helium Gasholder at low level.

(d) Low flow of the Fine Control Rod Secondary Coolant.

(e) Fine Control Rod Primary Coolant Temperature high.

(f) Less than three main light water cooling pumps running.

(g) Reactor D_2O outlet temperature high (flexible condition, see Section 2.6.3).

(h) D_2O Temperature Difference (inlet/outlet of reactor) high (flexible condition, see Section 2.6.3).

(i) D_2O total flow less than 650 lb/sec.

(j) Less than two main D_2O pumps running.

(k) The introduction of contacts of up to four experimental rigs, loops, etc. (normally bridged out if not in use).

(1) A number of other conditions arising largely from departures from normal operating procedures and discussed in Section 2.5.

2.2 The CONTROL REVERSAL Primary Guard Line (see Figure 1)

2.2.1 General

The primary guard line consists of a series connection of all those primary contacts on appropriate measuring instruments or equivalent sets of relay contacts that individually can initiate a CONTROL REVERSAL. At either end of this guard line are inserted the monitoring relays $\frac{CR\text{-}P1}{8}$ and $\frac{CR\text{-}P2}{8}$. Contacts from these relays in a self-hold and reset circuit are also connected in series with the line and 50V d.c. is applied overall (see Figure 1).

A fault condition open-circuits one or more of the series connections, thereby de-energising the monitoring relays.

2.2.2 Operating contacts

(a) Control Arm Up-limit Switches. Mounted in the head unit of each control arm are a number of microswitches which are operated by movement of the control arm. One of these switches from each control arm, Bl_1-UL1 to Bl_6-UL1 respectively, is connected in a series network so that when any control arm exceeds its preset top limit of approximately 55.7° then this series chain is open-circuited. This network is incorporated in the CONTROL REVERSAL primary circuits.

(b) Opening of D_2O Plant Room Doors. Two heavy shielded doors have been provided for access to the Heavy Water Plant Room. As a major health hazard exists in this room when the reactor is operating at full power, both doors are kept locked. The only key, No. 8, to these doors is trapped in Control Room Panel No. 1 in the Lock-out switch No. 6 which is labelled D_2O PLANT ROOM DOORS. If, when the reactor is operating, the key is turned from the operational position, a CONTROL REVERSAL will be started (see Section 2 and Manual M7 for details). This one key, No. 8, can be used to open only one of the Heavy Water Plant Room doors at a time. When a door is properly closed, the key is necessary to unlock the door mechanically thereby trapping the key in the lock. This action also open-circuits the contacts PRD-1 or PRD-2 corresponding to Plant Room doors Nos. 1 or 2. These contacts are connected in series and inserted in the CONTROL REVERSAL Primary Guard Line.

(c) Reactor Helium Gasholder Level Low. Two microswitches are operated mechanically by the helium gasholder level indicator so that at 5 per cent of capacity it open circuits. One, L6C-1, is inserted in the Primary CONTROL REVERSAL Circuits and the other, L6C-2, is inserted in the Secondary CONTROL REVERSAL Circuits.

(d) Fine Control Rod Secondary Coolant Flow. Up to 6 kW of heat can be generated in the Fine Control Rod depending on its position in the reactor. This heat is removed by a demineralised water circuit via a small heat exchanger (see Manual M31 for further information). The secondary side of the heat exchanger is cooled by a branch of the shield cooling water circuit whose flow is monitored by a type of orifice plate, 5-FT-24, which is inserted on the shell side of the heat exchanger. The differential pressure tapping points are taken to a differential pressure switch, made by Delta Technical Services Ltd., 5-FT-24, which uses the principle of opposing stainless steel bellows. Microswitch F24-1 operated by this instrument is incorporated in the CONTROL REVERSAL primary circuits. Microswitch F24-2 is incorporated in the CONTROL REVERSAL secondary circuits. These switches are set to trip at approximately 80 per cent of full flow, F24-2 operating just before F24-1. Only a very rough indication of the flow is given on the scale attached to 5-FT-24.

(e) Fine Control Rod Primary Coolant Temperature. The primary measuring element is the bulb of a vapour pressure thermometer located in the outlet pipe of the primary side of the Fine Control Rod Heat Exchanger. The bulb is connected via approximately 20 feet of capillary tubing to an 8 inch dial thermometer mounted on the outside wall of the Experimental Cooling Water Room facing the shield cooling water pumps. The pointer of the instrument open-circuits a single contact which can be preset to any temperature in the range 0-100°C. It has been set to operate at 50°C. The manufacturer of the instrument (Short and Mason) could supply only one contact. The two contacts required for incorporation of this parameter into the CONTROL REVERSAL circuits are provided by using the pointer-operated contact to control a Sunvic relay unit, which is mounted near the thermometer case (see Dwg. E.2763 for details of these connections). The two contacts in the Sunvic relay unit are labelled T52-1 and T52-2; the former is incorporated in the

CONTROL REVERSAL primary circuits and the latter in the CONTROL REVERSAL secondary circuits.

Note: As the Sunvic relay unit is a thermal device there is a 12-second time delay before either T52-1 or T52-2 operate after the opening of the primary contact on the instrument pointer.

(f) Condition of Main Pumps for Circulating Cooling Water. In the Pump-house there are four of these pumps and in normal operation of the reactor three are required to be running. Contacts on the motor starter switches operate auxiliary relays which provide additional contacts for incorporation into the safety circuits (see Manual M16 for details). Two contacts of the auxiliary relays P6-X1 for each pump are connected in a network in such a way that if less than three pumps are operating, the whole network is open-circuited. The network is incorporated in the CONTROL REVERSAL primary circuits. Two further contacts of the auxiliary relay P6-X2 for each pump are connected in a network so that if less than three pumps are operating, the whole network is open-circuited. The network is incorporated in the CONTROL REVERSAL secondary circuits.

(g) Heavy Water Flow. The primary measuring element is one or more Dall tubes (similar to short Venturi tubes) inserted in each of the four 7 inch diameter outlet pipes from the reactor. The pressure tappings from the Dall tubes are brought to common H.P. and L.P. headers. The differential pressure between the headers is fed to a Foxbro pneumatic transmitter which supplies outputs to various instruments including the pressure switches F20-B1 and F20-B2. They are set to trip at a pressure corresponding to a D_2O mass flow rate of 650 lb/sec, F20-B2 operating slightly before F20-B1. Contacts on switch F20-B1 are incorporated in the CONTROL REVERSAL primary circuits and contacts on switch F20-B2 are incorporated in the CONTROL REVERSAL secondary circuits. (See manuals M29 and M37 for further details of the instruments.)

(h) Heavy Water Outlet Temperature. This is a flexible condition (see Section 2.6.3) and at present is connected into the RESTRICTED TRIP circuits.

The primary measuring element is a platinum resistance thermometer (Heraeus type) located in the 10 inch suction header into which the four

7 inch outlet pipes from the reactor are joined. This function can be bypassed by using the Bypass Switch, located in Panel No. 1 in the Control Room. It is behind a transparent door and is operated by a black pointed knob, not by a key, as are all the other switches on this sub-panel. The purpose of all switches on this unit is discussed in Manual M1, and the details of circuit operation in the relevant manuals. To unlock the transparent door, key HIFAR 10, labelled BYPASS SWITCH PANEL DOOR, is rotated and removed from the lock at the top left of the sub-panels in Panel 5 in the Control Room. This key fits only these two locks. When it is removed from Panel 5 or when the transparent door is open, it is not possible to withdraw any controlling absorbers from the reactor core while the reactor is operating. Any absorber can always be inserted in any of the normal ways. Circuit arrangements to achieve this are discussed in Manuals M10 and M11 (see Dwgs. BE 3886 and AE 3965).

The Bypass Switch has 3 positions labelled NORMAL, γ-HEALTH, and D_2O OUTLET TEMP. When the switch is rotated from its normal position a warning bell sounds and the BYPASS SWITCHES sign comes on in the Annunciator on Control Room Panel No. 6. For operation of these warnings see Manuals M5 and M23, Dwgs. AE 3971 and AE 3997. The audible warning can be cancelled by pressing the WARNING BELL CANCEL button on Panel No. 5. The warning sign cannot be cancelled unless the Bypass switch is returned to NORMAL.

When the Bypass switch is set to D_2O OUTLET TEMP., one set of contacts A_4B_4 on Level 1 bridges out the contacts T3-A in the Primary Guard Line. Another set of contacts E_4F_4 on Level 2 bridges out contacts 1, 2 and 3 from the Secondary Guard Monitor Relay T3-ZT that are connected in the Secondary Guard Line.

If the reactor is operating when the bypassing is done it can continue to operate. Now, when there is a high D_2O outlet temperature, only visual and audible warnings will be given in the Control Room on the Fault Analysis Display and Annunciator in Panel No. 4.

It should be noted that it is not possible to reset Secondary Guard Relay, $\frac{\text{T3-ZT}}{6}$, when bypassed if it is released while the reactor is operating. This is because the Main Control Switch in Control Room

Panel No. 5 must be in the OFF position to allow resetting of RESTRICTED TRIP relays whereas it is in the OPERATIONAL position as HIFAR is at power. The only way to reset relay T3-ZT is to operate manually its armature in relay set No. 3.* If the circuit is cleared then relay T3-ZT will stay energised as indicated by the cancellation of visual indications. Then the Bypass Switch can be returned to NORMAL without the risk of shutting down the reactor.

The resistance thermometer is connected to the indicating potentiometric recorder (Unit 8) in Control Room Panel No. 6. Contacts T3-1 operated by this recorder are incorporated in the CONTROL REVERSAL primary circuits. They are set to trip at 55°C, the T3-2 contacts operating slightly before the T3-1. (See Manuals M36 and M37 for further details.)

(i) Heavy Water Temperature Difference - Inlet/Outlet of Reactor. This is a flexible condition (see Section 2.6.3) and at present is connected into the RESTRICTED TRIP circuits (see Manual M3). The primary measuring elements are platinum resistance thermometers (Heraeus types). One is inserted in each of the three 9 inch diameter inlet pipes to the reactor and one in each of the inlet bends to the main heat exchangers. All six of these thermometers are connected to a selector switch in the potentiometric indicating recorder (Unit 7 in Control Room Panel 6) so that the temperature difference across each heat exchanger can be measured. A bypass plug and socket are provided in the recorder to bypass the function while the different pairs of thermometers are selected. This is done daily at midnight as a check on thermal power and after the check is completed the bypass plug is withdrawn so that the safety circuit is fully operational. Contacts T2-1 operated by this recorder are incorporated in the CONTROL REVERSAL primary circuits. Contacts T2-2 operated by this recorder are incorporated in the RESTRICTED TRIP secondary circuits. They are set to trip at a temperature difference of 8°C, the T2-2 contacts operating slightly before the T2-1. (See Manuals M36 and M37 for further details.)

---

* Manual operation of relay armatures is not accepted practice. The fact that it is mentioned in this manual does not authorise it as an operation.

(j) Condition of the Main Heavy Water Circulating Pumps. In the Heavy Water Plant Room there are three of these pumps and in normal operation of the reactor two are required to be running. Contacts on the motor starter switches operate the auxiliary relays which provide additional contacts for incorporation into the safety circuits (see Manual M13 for details). Two contacts of the auxiliary relay P1-X1 for each pump are connected in a network so that if less than two pumps are operating, the network is open-circuited. This network is incorporated in the CONTROL REVERSAL primary circuits. Two further contacts of the auxiliary relay P1-X2 for each pump are connected in a network so that if less than two pumps are operating the network is open-circuited. This network is incorporated in the CONTROL REVERSAL secondary circuits.

(k) Experimental Rigs. Provision has been made for introducing into the safety circuits contacts from up to four separate experimental rigs or loops. Normally, these will be used only if the rig or loop has parameters which can affect the safety or operation of the reactor. For each rig or loop one independent contact which open-circuits on fault is required to be incorporated in the CONTROL REVERSAL primary guard line and another independent contact in the CONTROL REVERSAL secondary circuits. Where these circuits are not in use for including rigs or loops, the insertion terminals are permanently bridged out in Junction Box No. 12 on top of the reactor.

(l) Shutdown Buttons. Provision has been made for introducing into the CONTROL REVERSAL circuits Emergency Shutdown buttons. At present all Emergency Shutdown buttons are included in the RESTRICTED TRIP circuits. Appropriate terminals on terminal block 1-T1 must be unbridged and the switch contacts inserted.

(m) No other parameter is connected directly into the CONTROL REVERSAL circuits, but under certain conditions as discussed in Section 2.5 the effect of a CONTROL REVERSAL can be initiated.

2.2.3 Primary guard line monitoring relays

Relays $\frac{\text{CR-P1}}{8}$ and $\frac{\text{CR-P2}}{8}$ are the primary guard line monitoring relays. They are concerned with the following circuits:

(i) Contacts 1, 2 and 3 of each relay are connected in series with the 50V feed to relay coil $\frac{\text{B1-F1}}{3+2}$ (see Dwg BE3886) via contacts 2 and 3 of relay $\frac{B1-C}{6}$. De-energising relay $\frac{B1-F1}{3+2}$ and energising either of relay coils $\frac{B1-E1}{3+2}$ or $\frac{B1-E2}{3+2}$ causes the Coarse Control Arms to be driven in fast.

(ii) Contacts 4, 5 and 6 of each relay are not used.

(iii) Contacts 11, 12 and 13 of each relay are connected in series with the 50V feed to the relay coil $\frac{B1-F2}{3+2}$ (see Dwg. BE 3886) via contacts 22 and 23 of relay $\frac{B1-C}{6}$. De-energising relay $\frac{B1-F2}{3+2}$ and energising either of relay coils $\frac{B1-E1}{3+2}$ or $\frac{B1-E2}{3+2}$ causes the Coarse Control Arms to be driven in fast.

(iv) Contacts 14, 15 and 16 of each relay are not used.

(v) Contacts 21, 22 and 23 of each relay are inserted in series with the CONTROL REVERSAL primary guard line, contacts 21, 22 and 23 of relay CR-P1 being adjacent to coil $\frac{CR-P2}{8}$ and vice versa. Thus these contacts are in a holding circuit. Resetting of the guard line is achieved by means of the reset relay contacts $CR\text{-}RZ_a$ and $CR\text{-}RZ_b$ in parallel with the above contacts. The resetting system is discussed later in Section 2.4.

(vi) Contacts 24, 25 and 26 of each relay are connected in series with the coil of relay $\frac{CR-G}{6}$ (see Dwg AE 3996). This relay is effectively a slave relay to provide further contacts for use in circuits requiring to know when the reactor is in the CONTROL REVERSAL condition. The use of these contacts is described in Section 2.3.5.

(vii) Contacts 31, 32 and 33 of relay $\frac{CR-P1}{8}$ light the CONTROL REVERSAL sign in Control Room Panel No. 4. Annunciator Panel (see Dwg E5364).

(viii) Contacts 31, 32 and 33 of relay $\frac{CR-P2}{8}$ are inserted in the series chain of contacts which operate the audible alarm circuit so that if the line is open-circuited a bell sounds in the Control Room (see Circuit AE 3997 and Manual M23).

(ix) Contacts 34, 35 and 36 of relay $\frac{CR-P1}{8}$ light the CONTROL REVERSAL Primary Fault light (5/FA-C/L17) in the fault analysis display in Control Room Panel No. 5 (see Dwg E5365).

(x) Contacts 34, 35 and 36 of relay $\frac{CR-P2}{8}$ are not used.

2.3 The CONTROL REVERSAL Secondary Guard Circuits (see Figure 2)

2.3.1 Secondary guard relays

Secondary contacts on measuring instruments or equivalent sets of relay contacts that can initiate a CONTROL REVERSAL are each used to operate an individual relay called the Secondary Guard Relay (see Manual M1). A fault condition open-circuits the contacts thereby releasing the particular guard relay.

Note: It is customary to arrange for these relays to release a fault condition just before the primary guard line contacts so that detailed visual indication is immediately available on the fault analysis display in Control Room Panel No. 5.

2.3.2 Operating contacts

In most cases these have been listed and briefly described under "Operating Contacts" for the primary guard line in Section 2.2.2 above. Only differences relevant to the Secondary Guard Circuits are outlined below. Resetting is discussed in Section 2.4.

(a) Control Arm Up-Limit Switches. There are six separate micro-switches, one for each control arm. Contacts from these switches are connected in series and this group is then connected in series with secondary guard relay coil $\frac{\text{B1-Z2}}{6}$ and its holding and resetting contacts.

(b) Opening of Heavy Water Plant Room Doors. Microswitches PRD1-2 and PRD2-2 operated by movement of either door are connected in series. These contacts are connected in series with secondary guard relay coil $\frac{\text{PDR-Z}}{6}$ and its holding and resetting contacts.

(c) Reactor Helium Gasholder Low. Contacts of microswitch, L6C-2, operated by the helium gasholder level indicator are connected in series with secondary guard relay $\frac{\text{L6C-Z}}{6}$ and its holding and resetting contacts.

(d) Fine Control Rod Secondary Coolant Flow Low. Contacts F24-2 from the differential pressure switch 5-FT-24 are connected in series with the secondary guard relay coil $\frac{\text{F24-Z}}{6}$ and its holding and resetting contacts.

(e) Fine Control Rod Primary Coolant Temperature. Contacts T52-2 from the Sunvic relay are connected in series with the secondary guard relay coil $\frac{\text{T52-Z}}{6}$ and its holding and resetting contacts.

(f) Condition of Main Pumps for Circulating Cooling Water. Two contacts of each of the four auxiliary pump relays $P6_n - X_2$ are connected in a network so that if less than three pumps are operating the whole network is open circuited. The network is connected in series with the secondary guard relay coil $\frac{P6\text{-}Z2}{6}$ and its holding and resetting contacts.

(g) Heavy Water Flow. Contacts F20-B2 from a pressure switch, which is operated by a Foxboro differential pressure transmitter, are connected in series with the secondary guard relay coil $\frac{F20B\text{-}Z}{6}$ and its holding and resetting contacts.

(h) Heavy Water Outlet Temperature. This is a flexible condition and is connected into the RESTRICTED TRIP circuits. However, there is a secondary guard relay $\frac{T3\text{-}ZR}{6}$ and its associated holding and resetting contacts provided in the CONTROL REVERSAL secondary circuits. It is kept permanently energised by a link connection. For further discussion see Section 2.6.3.

(i) Heavy Water Temperature Difference. This is a flexible condition and is connected into the RESTRICTED TRIP circuits. However, there is a secondary guard relay $\frac{T2\text{-}ZR}{6}$ and its associated holding and resetting contacts provided in the CONTROL REVERSAL circuits. It is kept permanently energised by a link connection. For further discussion see Section 2.6.3.

(j) Condition of the Main Heavy Water Circulating Pumps. Two contacts of each of the three auxiliary relays $P1_n\text{-}X_2$ are connected in a network so that if less than two pumps are operating the whole network is open circuited. The network is connected in series with the secondary guard relay coil $\frac{P1\text{-}Z2}{6}$ and its holding and resetting contacts.

(k) Experimental Rigs. Four secondary guard relays $\frac{LR1\text{-}Z}{6}$, $\frac{LR2\text{-}Z}{6}$, $\frac{LR3\text{-}Z}{6}$ and $\frac{LR4\text{-}Z}{6}$ together with their associated holding and resetting circuits are provided. Any operating contacts can be inserted in Junction Box 12 on top of the reactor by removing the appropriate link.

(l) Emergency Shutdown Buttons. Although all these buttons are currently inserted in the RESTRICTED TRIP circuits, a secondary guard relay $\frac{EM\text{-}Z2}{6}$ and its holding and resetting circuits have been provided. Appropriate terminals on terminal block 1-T11 must be unbridged and the switch contacts inserted.

2.3.3 <u>Circuits associated with contacts on the secondary guard relays</u>

These concern relays $\frac{\text{B1-Z2}}{6}$, $\frac{\text{PRD-Z}}{6}$, $\frac{\text{L6C-Z}}{6}$, $\frac{\text{F24-Z}}{6}$, $\frac{\text{T52-Z}}{6}$, $\frac{\text{P6-Z2}}{6}$, $\frac{\text{T3-ZR}}{6}$ $\frac{\text{T2-ZR}}{6}$, $\frac{\text{F20B-Z}}{6}$, $\frac{\text{P1-Z2}}{6}$, $\frac{\text{LR4-Z}}{6}$, $\frac{\text{LR3-Z}}{6}$, $\frac{\text{LR2-Z}}{6}$, $\frac{\text{LR1-Z}}{6}$, $\frac{\text{EM-Z2}}{6}$.

(i) Contacts 1, 2 and 3 of each relay are all connected in series and together with the monitoring relays $\frac{\text{CR-Y1}}{8}$ and $\frac{\text{CR-Y2}}{8}$ and their holding and resetting contacts form the CONTROL REVERSAL Secondary Guard Line. When any of these contacts open circuit the line, the six control arms are driven fast into the core by circuits associated with the monitoring relays $\frac{\text{CR-Y1}}{8}$ and $\frac{\text{CR-Y2}}{8}$.

(ii) Contacts 4, 5 and 6 of each relay light the appropriate lights on the fault analysis display in Control Room Panel No. 5 (see Dwg E5365 and Manual M27 for details).

These lights are labelled respectively:

Relay Code	Corresponding Fault Analysis Display Light
B1-Z2	Control Arms Up Limit
PRD-Z	D_2O Plant Room Doors Open
L6C-Z	Reactor Helium Gasholder Empty
F24-Z	Fine Control Rod. Secondary Coolant Flow Low
T52-Z	Fine Control Rod. Primary Coolant Temperature High
P6-Z2	Main H_2O Pumps < 3
T3-ZR	D_2O Outlet Temperature High
T2-ZR	D_2O Temperature Difference High
F20B-Z	D_2O Flow $< 90\%$
P1-Z2	Main D_2O Pumps < 2
LR4-Z	Experimental Loop. CONTROL REVERSAL 4
LR3-Z	Experimental Loop. CONTROL REVERSAL 3
LR2-Z	Experimental Loop. CONTROL REVERSAL 2
LR1-Z	Experimental Loop. CONTROL REVERSAL 1
EM-Z2	Emergency Shutdown, CONTROL REVERSAL

(iii) Contacts 7, 8 and 9 of each relay are used to light signs in the Annunciator in Control Room Panel No. 4 (see Dwg. E5364 and Manual M26).

(iv) Contacts 21, 22 and 23 of each relay are not used.

(v) Contacts 24, 25 and 26 of each relay are connected in series and make up the CONTROL REVERSAL Audible Alarm circuit so that when the line is open circuited a bell sounds in the Control Room (see Dwg AE3997 and Manual M23).

(vi) Contacts 27, 28 and 29 of each relay are inserted in series and adjacent to their respective relay coils in a self holding circuit. In parallel with each of these sets of contacts are contacts from the reset relays $\frac{\text{CR-RZ}}{6}c$, $\frac{\text{CR-RZ}}{6}d$ and $\frac{\text{CR-RZ}}{6}e$. The resetting operation is discussed in Section 2.4.

2.3.4 <u>Secondary guard line monitoring relays</u>

These are relays $\frac{\text{CR-Y1}}{8}$ and $\frac{\text{CR-Y2}}{8}$ and they are concerned with the following circuits:

(i) Contacts 1, 2 and 3 of each relay are connected in series with the 50V feed to relay coil $\frac{\text{B1-F1}}{3+2}$ (see Dwg BE3886) via contacts 2 and 3 of relay $\frac{\text{B1-C}}{6}$. De-energising relay $\frac{\text{B1-F1}}{3+2}$ and energising either of relay coils $\frac{\text{B1-E1}}{3+2}$ or $\frac{\text{B1-E2}}{3+2}$ causes the control arms to be driven in fast.

(ii) Contacts 4, 5 and 6 of each relay are not used.

(iii) Contacts 11, 12 and 13 of each relay are connected in series with the 50V feed to the relay coil $\frac{\text{B1-F2}}{3+2}$ (see Dwg BE3886) via contacts 22 and 23 of relay $\frac{\text{B1-C}}{6}$. De-energising relay $\frac{\text{B1-F2}}{3+2}$ and energising either of relay coils $\frac{\text{B1-E1}}{3+2}$ or $\frac{\text{B1-E2}}{3+2}$ causes the control arms to be driven in fast.

(iv) Contacts 14, 15 and 16 of each relay are not used.

(v) Contacts 21, 22 and 23 of each relay are inserted in series with the CONTROL REVERSAL Secondary Guard Line, contacts 21, 22 and 23 of relay CR-Y1 being adjacent to coil $\frac{\text{CR-Y2}}{8}$ and vice versa. Thus these contacts are in a holding circuit. Resetting of the guard line is achieved by means of the reset relay contacts CR-RZ_a and CR-RZ_b in parallel with the above contacts. The resetting system is discussed in Section 2.4.

(vi) Contacts 24, 25 and 26 of each relay are connected in series with the coil of relay $\frac{\text{CR-G}}{6}$ (see Dwg AE3996). This relay is effectively a slave relay to provide further contacts for use in circuits requiring to know when the reactor is in the CONTROL REVERSAL condition. The use of these contacts is described in Section 2.3.5.

(vii) Contacts 31, 32 and 33 of relay $\frac{\text{CR-Y1}}{8}$ light the CONTROL REVERSAL sign in Control Room Panel No. 4 annunciator panel (see Dwg E5364).

(viii) Contacts 31, 32 and 33 of relay $\frac{\text{CR-Y2}}{8}$ are not used.

(ix) Contacts 34, 35 and 36 of relay $\frac{\text{CR-Y2}}{8}$ light the CONTROL REVERSAL Secondary Fault Light (5/FA-C/L18) in the fault analysis display in Control Room Panel No. 5 (see Dwg E5365).

(x) Contacts 34, 35 and 36 of relay $\frac{\text{CR-Y2}}{8}$ are not used.

2.3.5 The action of relay $\frac{\text{CR-G}}{6}$

It has been noted in Sections 2.2.3 (vi) and 2.3.4 (vi) that the Primary and Secondary Guard Line monitoring relays, $\frac{\text{CR-P1}}{8}$, $\frac{\text{CR-P2}}{8}$, $\frac{\text{CR-Y1}}{8}$ and $\frac{\text{CR-Y2}}{8}$ each have contacts in series with the coil of relay $\frac{\text{CR-G}}{6}$. The contacts of this relay are used in the following circuits:

(a) Contacts 1, 2 and 3 are connected in series with the 50V d.c. feed to relay coil $\frac{\text{B1-F1}}{3+2}$ via contacts 2 and 3 of relay $\frac{\text{B1-C}}{6}$. De-energising relay $\frac{\text{B1-F1}}{3+2}$ and energising either of relay coils $\frac{\text{B1-E1}}{3+2}$ or $\frac{\text{B1-E2}}{3+2}$ causes the control arms to be driven in fast.

(b) Contacts 4, 5 and 6 are connected in series with the 50V d.c. feed to relay coil $\frac{\text{B1-F2}}{3+2}$ via contacts 22 and 23 of relay $\frac{\text{B1-C}}{6}$. De-energising relay $\frac{\text{B1-F2}}{3+2}$ and energising either of relay coils $\frac{\text{B1-E1}}{3+2}$ or $\frac{\text{B1-E2}}{3+2}$ causes the control arms to be driven in fast.

(c) Contacts 7, 8 and 9 are connected in series with the Fine Control Rod RAISE switch (level 2) and contacts 22 and 23 of relay $\frac{\text{B2-A}}{4}$ to inhibit the Fine Control Rod "raise" function under CONTROL REVERSAL conditions.

(d) Contacts 21, 22 and 23 are connected in series with the Main Control Switch (level 2), contacts 22 and 23 of relay $\frac{\text{T-G1}}{6}$ and contacts 27 and 28 of relay $\frac{\text{G-SB}}{6}$ to provide a circuit for the operation of relay coil $\frac{\text{G-SA}}{2}$ (see Dwg AE3996 and Manual M7, Start Guard Circuits).

(e) Contacts 24, 25 and 26 are connected in series with the Control Arms RAISE switch so that operation of this switch is negated under CONTROL REVERSAL conditions.

(f) Contacts 27, 28 and 29 are used in the Control Arms position interlock control in series with contacts 5 and 6 of relay $\frac{\text{G-SC}}{4}$ to feed 50V d.c. to the "hold" coils of the six $\frac{\text{B1}_n\text{-M}}{6}$ relays and $\frac{\text{B1-DI}}{6}$ so that these relays remain energised under CONTROL REVERSAL conditions, not masking the indications from other circuits of the prime cause of the CONTROL REVERSAL. Under CONTROL REVERSAL conditions, and with the main control switch turned OFF releasing relay $\frac{\text{G-SC}}{4}$ at level 1, when any one of the six control arms reaches and operates its bottom limit switches, relay $\frac{\text{B1-DI}}{6}$ will be released, initiating the RESTRICTED TRIP Condition.

2.4 Resetting of Control Reversal Relays

The detailed operation of the reset system is described in manual M1. Pressing the Trip Reset button in Control Room Panel No. 5 energises the CONTROL REVERSAL reset system. It is not dependent on the position of any other switches nor relay contacts.

The two relay coils $\frac{\text{CR-RZ}}{4}$a and $\frac{\text{CR-RZ}}{4}$b are connected in parallel and energised by the spring returned push button TRIP RESET in Control Room Panel No. 5. Contacts on these relays are associated with resetting and operating the following circuits:

(a) Contacts 1, 2 and 3 of each relay are connected across the holding contacts $\frac{\text{CR-P2}}{8}$ and $\frac{\text{CR-P1}}{8}$ respectively in the CONTROL REVERSAL Primary Guard Line. The use of a set of contacts from each reset relay provides a check that the reset system is operating satisfactorily.

(b) Contacts 4, 5 and 6 of relay $\frac{\text{CR-RZ}}{4}$a are in series with the 50V d.c. feed to the three auxiliary reset relays $\frac{\text{CR-RZ}}{6}$c, $\frac{\text{CR-RZ}}{6}$d and $\frac{\text{CR-RZ}}{6}$e whose coils are connected in parallel. These relays provide an extra 18 sets of contacts for reset use.

(c) Contacts 4, 5 and 6 of $\frac{CR\text{-}RZ}{4}b$ are not used.

(d) Contacts 21, 22 and 23 of each relay are connected across the holding contacts $\frac{CR\text{-}Y2}{8}$ and $\frac{CR\text{-}Y1}{8}$ respectively in the CONTROL REVERSAL Secondary Guard Line. The use of a set of contacts from each reset relay provides a check that the resetting system is working satisfactorily.

(e) Contacts 24, 25 and 26 of $\frac{CR\text{-}RZ}{4}a$ are used in the audible alarm circuits to prevent the bells operating when the reset operation occurs (see Manual M23 and Dwg AE3997).

(f) Contacts 24, 25 and 26 of $\frac{CR\text{-}RZ}{4}b$ reset the $\frac{L\phi\text{-}G}{4}$ relay whose operation is discussed in manual M8 (see Dwg BE3998). Contacts on the auxiliary relays $\frac{CR\text{-}RZ}{6}c$, $\frac{CR\text{-}RZ}{6}d$ and $\frac{CR\text{-}RZ}{6}e$ are used to reset the CONTROL REVERSAL secondary guard relays. Contacts 27, 28 and 29 of $\frac{CR\text{-}RZ}{6}e$ constitute the only spare set of contacts.

2.5 Other Ways of Producing the CONTROL REVERSAL Condition

All the methods so far considered produce the CONTROL REVERSAL condition because the preset level of a physical parameter is exceeded. Certain departures from the normal operating procedures of the reactor will also directly initiate the CONTROL REVERSAL condition but, in general, will not give a direct indication of a CONTROL REVERSAL in either the fault analysis display or the annunciator. Sometimes there is only an indirect indication of the cause of the condition. Below is a list of all these other methods and their symptoms, assuming that the reactor is in its normal operational state and running at a steady power level. These are all associated with the operating circuit for relay $\frac{CR\text{-}G}{6}$ in the start guard circuit (see Dwg AE3996);

(a) If Level 2 of the Main Control Switch is turned from its ON position a CONTROL REVERSAL is initiated. At other levels on this switch a RESTRICTED TRIP is initiated so that effectively Level 2 ensures that the magnet poles are driven down to pick up the magnet armatures at the fully in rest position of the control arms.

(b) If any one of the Lockout Switches Nos. 2 to 8 inclusive, or the Coarse Control Arms Maintenance Selector Switch is rotated from its operational position, then relay $\frac{LO\text{-}G}{4}$ is released and contacts 21, 22 and 23 of this relay ensure that relay $\frac{CR\text{-}G}{6}$ is released.

(c) If the Reactor Helium Isolating Valve (Lockout Switch No. 1) Switch (Level 1) is turned from its operational position the circuit to relay coil $\frac{\text{CR-G}}{6}$ is broken and a CONTROL REVERSAL initiated.

(d) Release of relay $\frac{\text{G-SB}}{6}$ (Contacts 24, 25 and 26) which monitors the RESTRICTED TRIP conditions (see Dwg AE3996 and Manual M7).

2.6 The Flexibility Unit (See Dwg AE4006)

2.6.1 General

The flexibility unit in the centre of Control Room Panel No. 1 consists of a 512 way terminal block. It contains: 8 horizontal rows of terminals labelled A to H inclusive with A at the top.

64 vertical columns labelled 1 to 64 inclusive with 1 at the left, looking at the front of Control Room Panel No. 1.

All the primary and secondary contacts for the RESTRICTED TRIP and CONTROL REVERSAL conditions are brought to appropriate terminals on this unit. Hence it is a very useful centre for checking the operation of these circuits. Also, it provides the most convenient place to bridge out any parameter in these circuits after the necessary approval has been obtained.

Almost all the connections are in the +50V d.c. relay lines and only about 5 or 6 are in the 24V a.c. lines.

2.6.2 The coding system used in the flexibility unit

(i) Horizontal rows up to and including column No. 38

These are all +50V d.c. circuits.

Row A contains all contacts in the RESTRICTED TRIP primary guard line.

Row B contains all contacts operating RESTRICTED TRIP secondary guard relays.

Row C contains all contacts operating in the CONTROL REVERSAL primary guard line.

Row D is for use with flexible connections (see Section 2.6.3).

Row E contains all contacts operating CONTROL REVERSAL secondary guard relays.

Row F provides connection to all the series contacts in the RESTRICTED TRIP secondary guard line.

Row G is for use with bypass switch operations.

Row H provides connection to all the series contacts in the CONTROL REVERSAL secondary guard line.

(ii) Vertical columns from and including column No. 40

Columns 40 and 41 supply +50V d.c. to SCRAM and COMPLETE SHUTDOWN circuits.

Columns 43 and 44 supply +50V d.c. to RESTRICTED TRIP secondary circuits.

Columns 46 and 47 supply +50V d.c. to CONTROL REVERSAL secondary circuits.

Column 49 supplies +50V d.c. to fine control rod circuits.

Column 51 supplies +50V d.c. to coarse control arm master gearbox lower limit switch circuits.

Column 52 supplies +50V d.c. to audible alarm cutoff, reset, and start guard circuits.

Column 54 supplies 24V a.c. to RESTRICTED TRIP and CONTROL REVERSAL bell circuits.

Column 56 supplies +50V d.c. in coarse control arm time guard circuits.

2.6.3 Flexible conditions

In the initial design of the HIFAR circuits it was proposed that certain guard conditions should be able to initiate either a RESTRICTED TRIP or a CONTROL REVERSAL. The choice of type of reactor shutdown is to be regarded as permanent since soldered electrical connections have to be broken to alter it.

It is necessary to provide fully wired duplicate secondary guard relays in both the RESTRICTED TRIP and CONTROL REVERSAL secondary guard circuits. The relay which is not used must be permanently energised from the 50V d.c. supply or else it will open-circuit the guard line in which it is not to be used.

To make the changeover as simple as possible, appropriate connections are brought to the flexibility unit in the middle of Control Room Panel No. 1.

The only two connections regarded as flexible at present are:

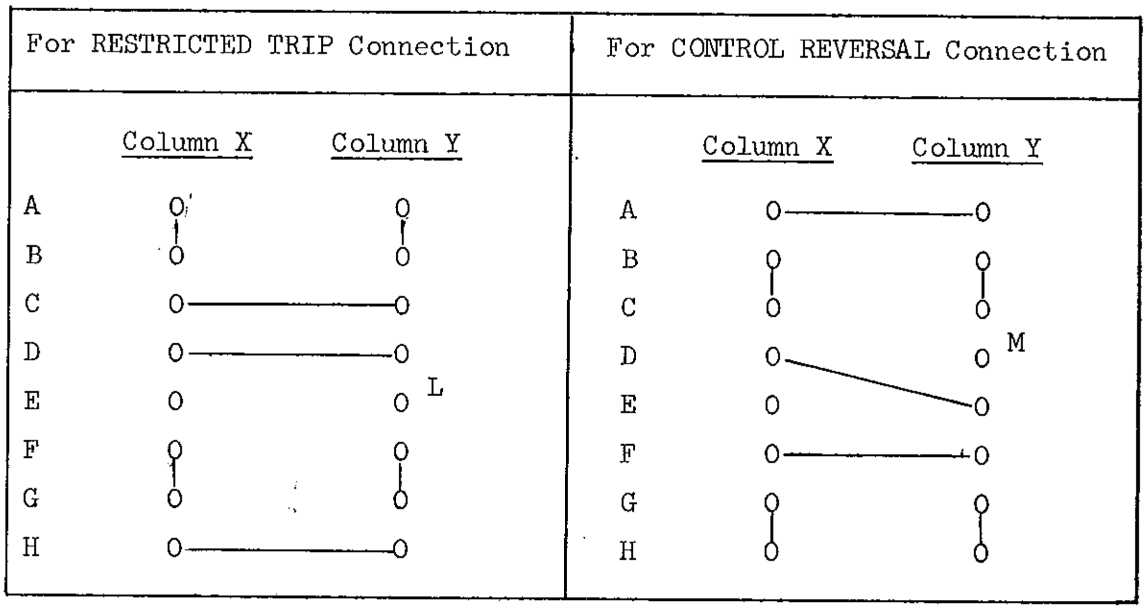
(i) Heavy water temperature difference high between inlet and outlet of the reactor; and

(ii) Heavy water outlet temperature from reactor high.

These two conditions are now permanently connected in the RESTRICTED TRIP circuits. If required condition (i) can be bypassed at the temperature difference recorder (see Section 2.2.2 (i)) and condition (ii) can be bypassed by the Bypass Switch in Control Room Panel No. 1 (see Section 2.2.2 (h) for details).

Arrangement of Interconnections

Front view, Column Nos. from Left to Right



KEY

In the case of	X	Y	Join L to	Join M to
D_2O Temp. Diff.	20	21	E36	D36
D_2O Outlet Temp.	22	23	E37	D37

Note: Straps in rows F, G, and H are only required in the case of the D_2O outlet temp. which has bypassing associated with it.

Re-arrangement of 50V d.c. Feed. It is also necessary to make some alterations to the common and 50V d.c. relay feed which is also available on the flexibility unit. These again are tabulated.

Condition	For RESTRICTED TRIP Connection		For CONTROL REVERSAL Connection	
	In Strapping Column 43 INCLUDE	In Strapping Column 46 OMIT	In Strapping Column 43 OMIT	In strapping Column 46 INCLUDE
D_2O Temp. Diff.	D43	D46	D43	D46
D_2O Outlet Temp.	E43	E46	E43	E46

APPENDIX 1

REACTOR HIFAR - LIST OF INSTRUMENTATION MANUALS

M1 Introduction to HIFAR Guard and Safety Circuits

M2 Complete Shutdown Circuits

M3 Trip Circuits

M4 Control Reversal Circuits

M5 Warning Circuits

* M6 Primary Search Unit

M7 Start Guard Circuits

* M8 Flux Trip Circuits

* M9 Safety Rod Circuits

* M10 Coarse Control Arm Circuits

* M11 Fine Control Rod Circuit

* M12 Dump Valve Circuit

* M13 Main Heavy Water Pump Circuit (S1)

* M14 Shutdown Heavy Water Pump Circuit (S2)

* M15 Transfer and Liquid Level Pump Circuits (S3 and S4)

* M16 Main H_2O Pump Circuits (S6)

* M17 H_2O Shutdown Circuits (S8)

* M18 Cooling Tower Fan Circuits (G8)

* M19 Shield Cooling Pump Circuits (S7)

* M20 Experimental Pump Circuits (S9)

* M21 Fine Control Rod Pump Circuits (S14)

* M22 Miscellaneous Circuits

24V circuits	4-LIA-10 circuit
50V d.c. circuits	4-L-15 circuit
240V circuits	Panel N

M23 Trip and Warning Alarm Circuits

* M24 Ventilation Flow Diagram Circuit

* M25 Main Flow Diagram and Cooling Tower Lamp Circuits

* M26 Annunciator Lamp Circuits

* M27 Fault Analysis Lamp Circuits

* M28 Principles of Operation of the Nucleonic Instruments

M29 The Control Room

* M30 The Coarse Control System

Continued...

REACTOR HIFAR - LIST OF INSTRUMENTATION MANUALS (Continued)

* not yet published

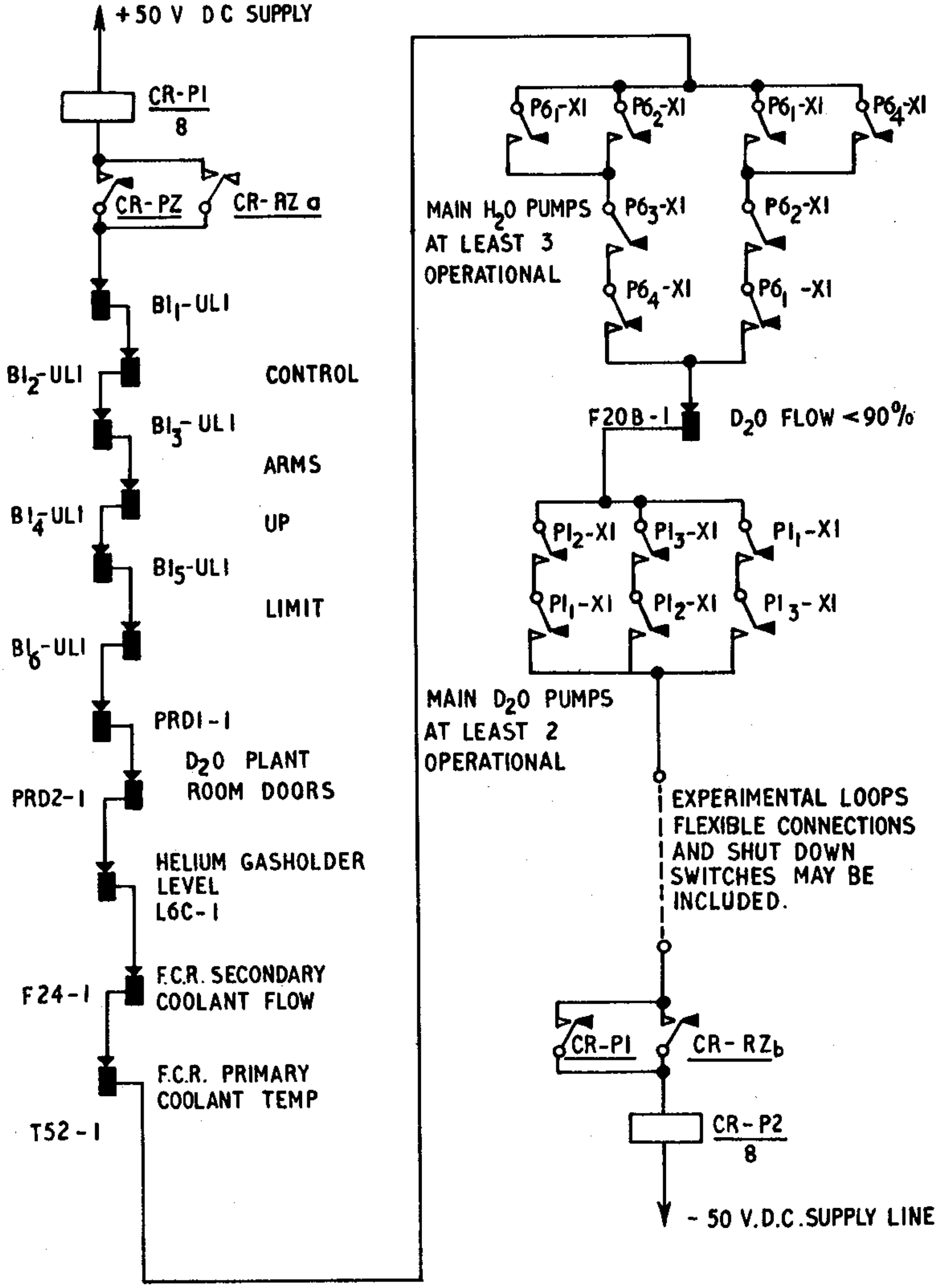


FIGURE 1. HIFAR - CONTROL REVERSAL PRIMARY GUARD CIRCUIT
(From Drawing No. E2270)

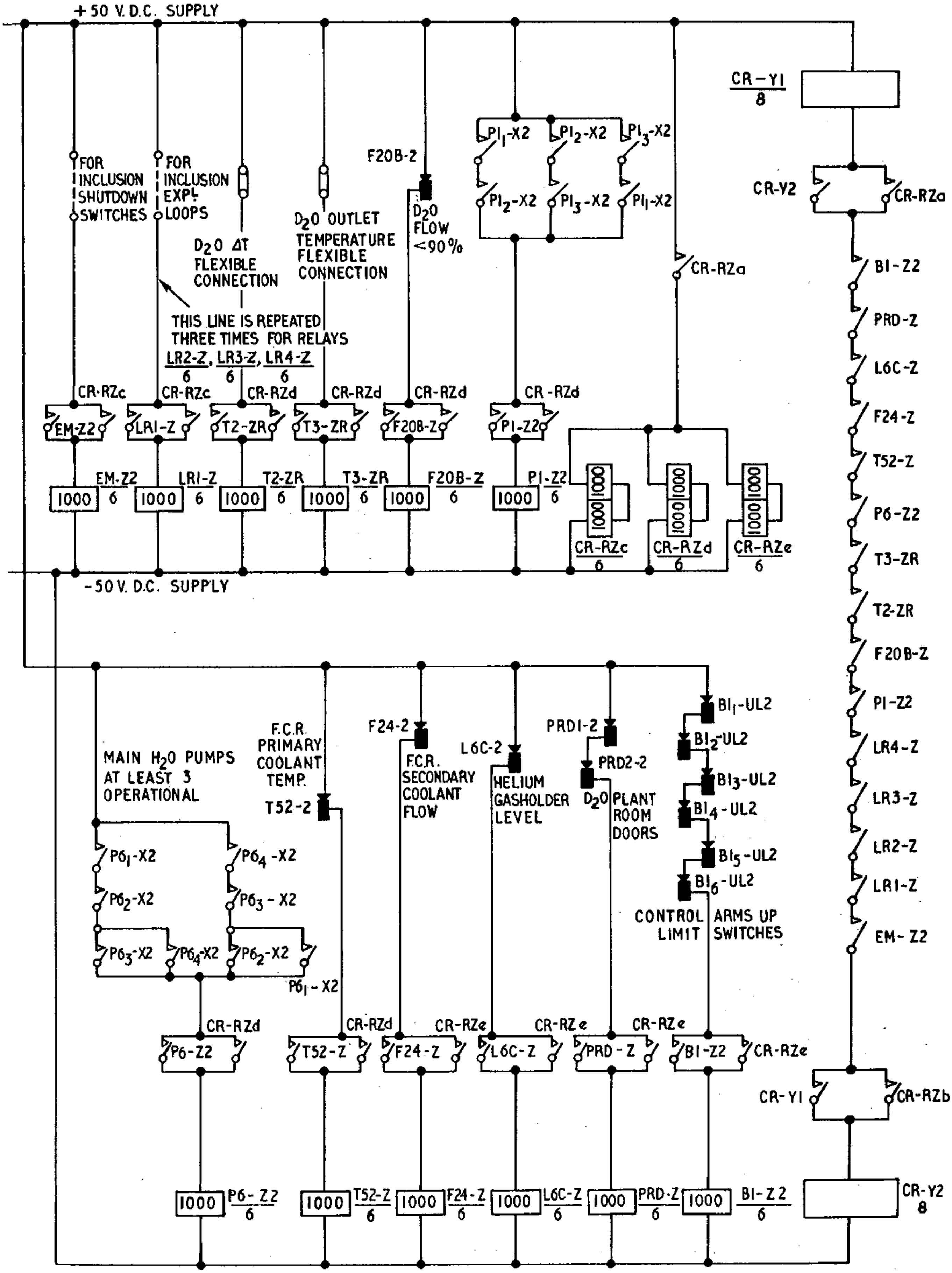


FIGURE 2. HIFAR - CONTROL REVERSAL SECONDARY GUARD CIRCUIT
(From Drawing No. E2271)