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RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

REACTOR HIFAR - THE CONTROL ARM CIRCUITS

by

W J SINCLAIR

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THE CONTROL ARM CIRCUITS

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ABSTRACT

This manual describes in detail the operation of the control arm circuits of the reactor HIFAR and their relation to other control and safety circuits.

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CONTENTS (continued)

1. INTRODUCTION

This manual is one of a series on the control, instrumentation and safety circuitry of the reactor HIFAR. Other manuals in the series are referred to in the text and the titles are listed in Appendix 2. The general reference is AAEC/M1, Reactor HIFAR: An introduction to the Guard and Safety Circuits, (Page 1959). A physical description of the control arm system is given in AAEC/M30 (Sinclair 1968).

The control arms move in response to the master gearbox power selsyn transmitter. This is driven by RAISE, SLOW DOWN and FAST DOWN motors (see AAEC/M30 for details). In this manual, unless specified otherwise, the description of control action to operate these driving motors is assumed to refer to the raising or lowering of the control arms at the appropriate speed.

2. LIFTING MAGNET CIRCUITS

Each magnet coil (Bl_n-MC) is energised over a similar but independent circuit to that shown in Figure 1 for number 1 magnet Bl_1-MC.

2.1 Normal Operation

Each circuit is complete under the following conditions:

(a) The Primary and Secondary COMPLETE TRIP and RESTRICTED TRIP guard conditions are safe. That is, the relays $\frac{\text{T-P1}}{8}$, $\frac{\text{T-P2}}{8}$, $\frac{\text{T-Y1}}{8}$ and $\frac{\text{T-Y2}}{8}$ monitoring the trip circuits are energised. The monitoring relay contacts are arranged in pairs on either side of the magnet coil, so that if only the primary or the secondary circuit fails, the magnet is disconnected from both the positive and negative (earthed) supply lines.

(b) The control relays $\frac{\text{Bl-Ba}}{8}$ and $\frac{\text{Bl-Bb}}{8}$ are operated. Action leading to the operation of these relays is described later (see Section 5.3), however the principal conditions which keep the relays operated are:

(i) The master switch in the HOLD position.

(ii) The main control switch in the OPERATIONAL position.

(iii) No. 2 lockout switch (absorbers and dump valve maintenance switch) in the OPERATIONAL position.

(iv) The relays $\frac{\text{Bl-K}}{3+2}$ $\frac{\text{Bl-E1}}{3+2}$ and $\frac{\text{Bl-E2}}{3+2}$ controlling power supply to the drive motors must be energised.

(v) The control arm magnet yokes and armatures must be in contact.

(vi) The control arms must be above the position marked by the down limit switches Bl_n-DL2 in the arm mechanisms.

Conditions (iv) and (vi) are initially provided for approximately two minutes by relays $\frac{G\text{-}TG}{4}$ and $\frac{G\text{-}SC}{4}$ in the Start Guard circuits (see AAEC/M7 for details).

2.2 Maintenance

When the control arms are selected for maintenance using No. 2 lockout switch, the control arm selector switch BlQS enables any one of the six magnet coils to be energised independently of the state of the trip circuits or the state of the relays $\frac{Bl\text{-}Ba}{8}$ and $\frac{Bl\text{-}Bb}{8}$. (See Section 9 for details).

3. POWER SUPPLY TO DRIVE MOTORS

The power supply to the motors is shown in Figure 2. The relays controlling their operation are shown in Figure 3.

The motors are energised from a 50 volt 3 phase supply obtained from a transformer behind Control Room Panel 3. The circuits to the SLOW DOWN motor are made through contacts of the control relay $\frac{Bl\text{-}L}{3+2}$, and to the FAST DOWN motors through contacts of the control relays $\frac{Bl\text{-}Fl}{3+2}$ and $\frac{Bl\text{-}F2}{3+2}$, all in the released condition. This ensures that on relay failure the control arms are driven down, but has made necessary the introduction of additional switching relays $\frac{Bl\text{-}K}{3+2}$ $\frac{Bl\text{-}El}{3+2}$ and $\frac{Bl\text{-}E2}{3+2}$ to switch off the supplies to the motors when the master gearbox reaches limiting positions in the downward direction. The state of the switching relays is continuously monitored by relays $\frac{Bl\text{-}Ba}{8}$ and $\frac{Bl\text{-}Bb}{8}$, and failure of any one results in the breaking of the magnet circuits to release the control arms.

Contacts of relay $\frac{Bl\text{-}K}{3+2}$ switch the RAISE motor in series with contacts of the control relay $\frac{Bl\text{-}R}{3+2}$ and the SLOW DOWN motor in series with contacts of the control relay $\frac{Bl\text{-}L}{3+2}$. Note that the control relay $\frac{Bl\text{-}R}{3+2}$ is energised to complete the circuit to the RAISE motor, while the control relays $\frac{Bl\text{-}L}{3+2}$, $\frac{Bl\text{-}Fl}{3+2}$ and $\frac{Bl\text{-}F2}{3+2}$ are de-energised to complete the circuits for the SLOW DOWN and FAST DOWN motors. Paralleled contacts of relays $\frac{Bl\text{-}El}{3+2}$ and $\frac{Bl\text{-}E2}{3+2}$ are used in series with paralleled contacts of $\frac{Bl\text{-}Fl}{3+2}$ and $\frac{Bl\text{-}F2}{3+2}$ to control the FAST DOWN motors.

4. OPERATIONAL REQUIREMENTS (see Figure 3)

4.1 Conditions at Start-Up

(a) The master gearbox and control arms are at 0°.

(b) Relays $\frac{\text{B1-E1}}{3+2}$ and $\frac{\text{B1-E2}}{3+2}$ are released, being disconnected by the Fast Motor Lower Electrical Limit Switches B1-EL3 and B1-EL4 respectively in the master gearbox.

(c) Relay $\frac{\text{B1-K}}{3+2}$ is released, being disconnected by the Slow Motors Lower Electrical Limit Switch B1-EL1 in the master gearbox.

(d) Relays $\frac{\text{B1-R}}{3+2}$, $\frac{\text{B1-L}}{3+2}$, $\frac{\text{B1-F1}}{3+2}$ and $\frac{\text{B1-F2}}{3+2}$ are released.

4.2 Operational Conditions Allowing Control Arms to be Raised

(a) The master switch must be in the HOLD position.

(b) The main control switch must be in the OPERATIONAL position.

(c) No. 2 lockout switch must be in the OPERATIONAL position.

(d) The FAST DOWN and SLOW DOWN Switches must be normal.

(e) The Lockout By-pass Panel door must be closed and the key guard switch on panel 5 must be in the OPERATIONAL position, trapping key HIFAR 10 in Panel 5.

(f) The lifting magnet circuits must be complete.

(g) Initially the master gearbox must be at 0° and the lower electrical limit switch B1-EL2 operated to prepare a circuit to relay $\frac{\text{B1-G}}{2}$. Subsequently the Divergency warning has been given and relay $\frac{\text{SW-B}}{8}$ is operated to provide an alternative circuit to relay $\frac{\text{B1-G}}{2}$. (See AAEC/M7 for operation of Divergency Unit).

(h) The raise time guard relay $\frac{\text{B1-TG}}{2}$ must have been operated and released, and its delayed release contact B1-TG2 must be still operated (see Section 5.3 below).

(i) The master gearbox must not have reached the upper electrical limit to operate switch B1-EL5.

(j) The FAST DOWN and SLOW DOWN motor relays $\frac{\text{B1-F1}}{3+2}$, $\frac{\text{B1-F2}}{3+2}$ and $\frac{\text{B1-L}}{3+2}$ must be operated.

5. NORMAL OPERATION

5.1 Before Raising Arms (see Figure 3)

(a) The master gearbox is at 0° and the lower electrical limit switches provide the following functions:

(i) B1-EL1 disconnects the SLOW DOWN motor relay $\frac{\text{B1-K}}{3+2}$.

(ii) Bl-EL2 prepares an initial circuit to relay $\frac{Bl\text{-}G}{2}$. Relay $\frac{Bl\text{-}G}{2}$ acts only as an interconnecting device between the 50 volt d.c. supply and a 240 volt a.c. mains operated timing relay $\frac{Bl\text{-}TG}{2}$. Both are mounted in the Time Guard Unit behind Control Room Panel 3 (unit 7). Only one set of contacts, 11, 12 and 13 of relay Bl-G, is used. Relay $\frac{Bl\text{-}TG}{2}$ is described in Appendix 1.

(iii) Bl-EL3 and Bl-EL4 disconnect the FAST DOWN motor relays $\frac{Bl\text{-}El}{3+2}$ and $\frac{Bl\text{-}E2}{3+2}$ respectively.

(b) The control arm mechanisms are at 0° and the magnet faces are in contact with their respective armatures. Regardless of the previous operating history which resulted in the control arms reaching 0°, the control arm mechanism magnet face switches Bl_n-MEl should be closed (see Figure 4). As the start guard circuit relay $\frac{G\text{-}SC}{4}$ is released, the reset magnet relay $\frac{Bl\text{-}RM}{6}$ is energised. Each springset of the latter relay is used in parallel with a springset from one of the magnet control relays $\frac{Bln\text{-}M}{6}$ and in series with the corresponding control arm magnet face switch Bl_n-MEl. The circuits to the $\frac{Bln\text{-}M}{6}$ relays are therefore complete and they are energised.

(c) Relay $\frac{Bl\text{-}DI}{6}$ is also energised by a released contact of the Start Guard circuit relay $\frac{G\text{-}SC}{4}$ (Figure 4).

(d) Relay $\frac{Bl\text{-}D}{4}$ is operated over the six down limit switches Bl_n-DLl in series (see Figure 5).

(e) Relay $\frac{Bl\text{-}I}{6}$ is operated over a series chain of contacts, one from each of the relays $\frac{Bln\text{-}M}{6}$ and from relay $\frac{Bl\text{-}DI}{6}$.

(f) Relays $\frac{T\text{-}Gl}{6}$ and $\frac{T\text{-}G2}{6}$ in the Start Guard circuit are operated over contacts from the primary and secondary RESTRICTED TRIP guard line monitoring relays $\frac{T\text{-}P2}{8}$ and $\frac{T\text{-}Y2}{8}$ respectively, provided that the RESTRICTED TRIP guard lines are cleared.

5.2 Start Sequence (Figure 3)

(a) Conditions (c), (d), (e) and (f) of Section 4.2 prepare a circuit to the control relays $\frac{Bl\text{-}Ba}{8}$ and $\frac{Bl\text{-}Bb}{8}$.

(b) The master switch in Panel 3 unit 5 must be in the HOLD position. At level 4 this switch provides + 50 volts d.c. feed to level 3 of the main control switch.

(c) The main control switch in Panel 5, unit 3, sub-unit d, is turned to

OPERATIONAL. At level 3 this switch provides + 50 volts d.c. feed to No. 2 lockout switch at levels 4 and 6.

(d) No. 2 lockout switch must be in the OPERATIONAL position. At level 4 this switch extends the + 50 volt d.c. feed to the chain of contacts which will hold the control relays $\frac{\text{B1-Ba}}{8}$ and $\frac{\text{B1-Bb}}{8}$ operated after the first operation of the RAISE switch.

At level 6 the + 50 volt d.c. feed is extended:

(i) to the FAST DOWN motor control relays $\frac{\text{B1-F1}}{3+2}$ and $\frac{\text{B1-F2}}{3+2}$ via a chain of contacts in series with each. This chain is not complete at the instant of turning the main control switch to OPERATIONAL as relay $\frac{\text{B1-C}}{6}$ has not been operated,

(ii) to energise relay $\frac{\text{B1-A}}{4}$ over the back contacts of the RAISE switch in its normal position and contacts 34 and 35 of relay $\frac{\text{B1-R}}{3+2}$ (released),

(iii) to the operational contact of the RAISE switch in parallel with contacts 32 and 33 of relay $\frac{\text{B1-R}}{3+2}$ which at the instant of turning the main control switch to OPERATIONAL is in the released condition,

(iv) to contact 23 of relay $\frac{\text{B1-P}}{4}$ (de-energised) via contacts 25 and 26 of relay $\frac{\text{B1-A}}{4}$ (operated), preparing a circuit for the operation of relay $\frac{\text{B1-G}}{2}$.

(e) Relay $\frac{\text{B1-A}}{4}$ operating:

(i) provides a separate self-holding circuit via contacts 1, 2 and 3 in series with 21, 22 and 23 and the released timing contact B1-TG1 until relay $\frac{\text{B1-TG}}{2}$ operates.

(ii) prepares a circuit for the operation of relay $\frac{\text{B1-P}}{4}$ via contacts 4, 5 and 6,

(iii) prepares a circuit for the operation of relay $\frac{\text{B1-G}}{2}$ via the master gearbox lower electrical limit switch B1-EL2, contacts 22 and 23 of relay $\frac{\text{B1-P}}{4}$ released and contacts 24, 25 and 26 of relay $\frac{\text{B1-A}}{4}$.

5.3 First Operation of the RAISE Switch

(a) The back contacts 1 and 4 are opened leaving relay $\frac{\text{B1-A}}{4}$ energised over the self-holding circuit described in 5.2 (e) (i) above.

(b) The operational contacts 2 and 3 are closed, energising the control relays $\frac{B1\text{-}Ba}{8}$ and $\frac{B1\text{-}Bb}{8}$ via contacts 4, 5 and 6 of relay $\frac{B1\text{-}C}{6}$ released and the Start Guard circuit contacts 4, 5 and 6 of relays $\frac{G\text{-}SB}{6}$ and $\frac{G\text{-}TG}{4}$. (See AAEC/M7 for details of the operation of Start Guard circuit relays).

(c) The contacts of relays $\frac{B1\text{-}Ba}{8}$ and $\frac{B1\text{-}Bb}{8}$ are used in the following manner:

(i) Six springsets of each relay complete the control arm lifting magnet circuits (see Figure 1), those of $\frac{B1\text{-}Ba}{8}$ on the + 50 volt d.c. supply side of the lifting magnet coil, and those of $\frac{B1\text{-}Bb}{8}$ on the -ve line of the 50 volt supply (earthed).

Contacts 1, 2 and 3 of each relay are associated with magnet coil $B1_1$-MC.

Contacts 4, 5 and 6 of each relay are associated with magnet coil $B1_2$-MC.

Contacts 11, 12 and 13 of each relay are associated with magnet coil $B1_3$-MC.

Contacts 14, 15 and 16 of each relay are associated with magnet coil $B1_4$-MC.

Contacts 21, 22 and 23 of each relay are associated with magnet coil $B1_5$-MC.

Contacts 24, 25 and 26 of each relay are associated with magnet coil $B1_6$-MC.

(ii) Contacts 31, 32 and 33 of each relay are connected in series to energise relay $\frac{B1\text{-}C}{6}$ from the + 50 volt d.c. supply (Figure 3).

(iii) Contacts 34, 35 and 36 of each relay provide a holding circuit so that the relays are not released when relay $\frac{B1\text{-}C}{6}$ operates.

(d) The contacts of relay $\frac{B1\text{-}C}{6}$ are used in the following manner:

(i) Contacts 1, 2 and 3 are used in series with contacts 1, 2 and 3 of each of the relays $\frac{CR\text{-}G}{6}$, $\frac{CR\text{-}P1}{8}$, $\frac{CR\text{-}Y1}{8}$, $\frac{CR\text{-}P2}{8}$ and $\frac{CR\text{-}Y2}{8}$ monitoring the CONTROL REVERSAL condition. These relays are normally energised and a circuit is completed to energise the FAST DOWN motor control relay $\frac{B1\text{-}F1}{3 + 2}$.

(ii) Contacts 4, 5 and 6 change over, disconnecting the original operating feed to relays $\frac{\text{B1-Ba}}{8}$ and $\frac{\text{B1-Bb}}{8}$ and connecting it to relay $\frac{\text{B1-P}}{4}$ via contacts 4, 5 and 6 of relay $\frac{\text{B1-A}}{4}$ operated. $\frac{\text{B1-P}}{4}$ now operates.

(iii) Contacts 7, 8 and 9 disconnect the CONTROL ARMS NOT DOWN lamp on the shutdown state display panel 5 so that this lamp will not be lit when the reactor is in the operational state.

(iv) Contacts 21, 22 and 23 are used in series with contacts 4, 5 and 6 of relay $\frac{\text{CR-G}}{6}$ and contacts 11, 12 and 13 of each of the relays $\frac{\text{CR-P1}}{8}$, $\frac{\text{CR-Y1}}{8}$, $\frac{\text{CR-P2}}{8}$ and $\frac{\text{CR-Y2}}{8}$ monitoring the CONTROL REVERSAL condition. These relays are normally energised and a circuit is completed to energise the FAST DOWN motor control relay $\frac{\text{B1-F2}}{3+2}$.

(v) Contacts 24, 25 and 26 are used in series with contacts 31, 32 and 33 of relays $\frac{\text{B1-F1}}{3+2}$ and $\frac{\text{B1-F2}}{3+2}$ to energise the SLOW DOWN motor control relay $\frac{\text{B1-L}}{3+2}$ via the SLOW DOWN switch on panel 5.

(vi) Contacts 27, 28 and 29 are used to operate relay $\frac{\text{SW-A}}{2}$ in the Start Guard circuit. This in turn activates the Divergency Unit (see AAEC/M7 for details).

(e) The contacts of the fast motors control relays $\frac{\text{B1-F1}}{3+2}$ and $\frac{\text{B1-F2}}{3+2}$ are used in the following manner:

(i) Contacts 1, 2 and 3; 11, 12 and 13; and 21, 22 and 23 of these relays are connected in parallel. Both must be in the energised state to prevent the FAST DOWN motors from running (see Figures 2 and 3). When the master gearbox moves above the setting of the fast motor lower electrical limit switches B1-EL3 and B1-EL4, and the fast motor switching relays $\frac{\text{B1-E1}}{3+2}$ and $\frac{\text{B1-E2}}{3+2}$ are energised, the release of either of the control relays due to the operation of the FAST DOWN switch or safety circuit action will drive the FAST DOWN motors.

(ii) Contacts 31, 32 and 33 of each relay complete the circuit to relay $\frac{\text{B1-L}}{3+2}$ as described in paragraph (d) (iv) above.

(iii) Contacts 34, 35 and 36 of each relay are not used.

(f) The contacts of the slow down control relay $\frac{\text{B1-L}}{3+2}$ are used in the following manner:

(i) Contacts 1, 2 and 3; 11, 12 and 13; and 21, 22 and 23 prevent the SLOW DOWN motor from running (see Figures 2 and 3). When the master gearbox moves above the setting of the slow down limit switch B1-EL1 and the slow down switching relay $\frac{B1-K}{3+2}$ is energised, the release of the control relay due to the operation of the SLOW DOWN or FAST DOWN switches or safety circuit action will drive the SLOW DOWN motor.

(ii) Contacts 31, 32 and 33 prepare the circuit to the RAISE motor control relay $\frac{B1-R}{3+2}$ (Figure 3).

(iii) Contacts 34, 35 and 36 are used to energise the relay $\frac{B1-K}{3+2}$ so that it is not dependent on the master gearbox slow down electrical limit switch B1-EL1 while relay $\frac{B1-L}{3+2}$ is operated.

(g) The contacts of the FAST DOWN switching relays $\frac{B1-E1}{3+2}$ and $\frac{B1-E2}{3+2}$ are used in the following manner:

(i) Contacts 1, 2 and 3; 11, 12 and 13; 21, 22 and 23 of each relay are connected in parallel. If either relay is energised the 50 volt 3 phase 50 Hz power supply is switched to the FAST DOWN motors via the contacts of the control relays $\frac{B1-F1}{3+2}$ and $\frac{B1-F2}{3+2}$ (see Paragraph (e) (i) above).

(ii) Contacts 31, 32 and 33 of each relay are used with contacts 31, 32 and 33 of relay $\frac{B1-K}{3+2}$ to maintain the control relays $\frac{B1-Ba}{8}$ and $\frac{B1-Bb}{8}$ operated after the expiry of the Start Guard time interval when relay $\frac{G-TG}{4}$ releases (see AAEC/M7 for details and Para. (h) (ii) below).

(iii) Contacts 34, 35 and 36 of each relay are not used.

(h) The contacts of the SLOW DOWN switching relay $\frac{B1-K}{3+2}$ are used in the following manner:

(i) Contacts 1, 2 and 3; 11, 12 and 13; 21, 22 and 23 switch the 50 volt 3 phase 50 Hz power supply to the RAISE and SLOW DOWN motors via contacts of the control relays $\frac{B1-R}{3+2}$ and $\frac{B1-L}{3+2}$ respectively (see Figure 2).

(ii) Contacts 31, 32 and 33 are used in series with contacts 31, 32 and 33 of relays $\frac{B1-E1}{3+2}$ and $\frac{B1-E2}{3+2}$, and after the expiry of the Start Guard time interval when relay $\frac{G-TG}{4}$ releases, maintain the control relays $\frac{B1-Ba}{8}$ and $\frac{B1-Bb}{8}$ operated, (see AAEC/M7

for details). Thus if in normal operation any of the relays $\frac{B1\text{-}K}{3+2}$, $\frac{B1\text{-}E1}{3+2}$ or $\frac{B1\text{-}E2}{3+2}$ release, the control relays $\frac{B1\text{-}Ba}{8}$ and $\frac{B1\text{-}Bb}{8}$ are also released and the control arm magnet circuits are broken.

(iii) Contacts 34, 35 and 36 are not used.

(i) When relay $\frac{B1\text{-}P}{4}$ operates:

(i) Contacts 1, 2 and 3 provide a holding circuit so that when relay $\frac{B1\text{-}A}{4}$ releases, the relay $\frac{B1\text{-}P}{4}$ will remain operated until relay $\frac{B1\text{-}R}{3+2}$ has operated and released.

(ii) Contacts 4, 5 and 6 prepare the circuit for operation of the RAISE motor control relay $\frac{B1\text{-}R}{3+2}$.

(iii) Contacts 21,22 and 23 complete the circuit to the relay $\frac{B1\text{-}G}{2}$ which is the switching relay for the timing relay $\frac{B1\text{-}TG}{2}$. Both these relays are therefore energised.

(iv) Contacts 24, 25 and 26 are not used.

(j) Relay $\frac{B1\text{-}TG}{2}$ is identical to relay $\frac{G\text{-}TR}{2}$ used in the Start Guard circuits and is described in Appendix 1. When the relay is energised, contact B1-TG1 releases relay $\frac{B1\text{-}A}{4}$. The other feed to relay B1-A has been disconnected by the pressing of the RAISE switch. Contact B1-TG2 prepares the cicuit to the RAISE motors control relay $\frac{B1\text{-}R}{3+2}$.

(k) Relay $\frac{B1\text{-}A}{4}$ releasing:

(i) disconnects its self-hold circuit at contacts 1, 2 and 3,

(ii) disconnects a parallel feed to relay $\frac{B1\text{-}P}{4}$ at contacts 4, 5 and 6,

(iii) further prepares the circuit to relay $\frac{B1\text{-}R}{3+2}$ at contacts 21, 22 and 23,

(iv) disconnects the feed to relay $\frac{B1\text{-}G}{2}$ at contacts 24, 25 and 26. Relay $\frac{B1\text{-}G}{2}$ releases and its contacts break the circuit to relay $\frac{B1\text{-}TG}{2}$ which releases.

(l) When relay $\frac{B1\text{-}TG}{2}$ is released:

The immediate release contact B1-TG1 (released) and the delayed release (timing) contact B1-TG2 (operated) complete the circuit to the RAISE motor control relay $\frac{B1\text{-}R}{3+2}$ via contacts 4, 5 and 6 of relay $\frac{B1\text{-}P}{4}$ and the supply circuit to relay $\frac{B1\text{-}P}{4}$.

(m) Relay $\frac{B1\text{-}R}{3+2}$ operating:

(i) applies the 50 volt 3 phase 50 Hz supply to the RAISE motors via its contacts 1, 2 and 3; 11, 12 and 13; and 21, 22 and 23 and contacts of relay $\frac{B1-K}{3+2}$ operated (Figure 2),

(ii) provides a holding circuit across the RAISE switch operational contacts by its contacts 31, 32 and 33 (Figure 3),

(iii) prevents re-operation of relay $\frac{B1-A}{4}$ when the RAISE switch is released on to its back contact by its contacts 34, 35 and 36.

(n) At the expiry of the time delay set by the adjustment of relay $\frac{B1-TG}{2}$, the contact B1-TG2 will release to de-energise the relay $\frac{B1-R}{3+2}$, which on releasing:

(i) stops the RAISE motor,

(ii) re-operates relay $\frac{B1-A}{4}$,

(iii) breaks the holding circuit across the RAISE switch operating contacts and releases relay $\frac{B1-P}{4}$.

The circuit is then ready for the second operation of the RAISE switch.

5.4 Subsequent Operation of the RAISE Switch

(a) Relay $\frac{B1-A}{4}$ has already operated and:

(i) self-holds via B1-TG1 contact,

(ii) prepares the circuit for relay $\frac{B1-P}{4}$,

(iii) prepares the circuit for relay $\frac{B1-G}{2}$.

(b) RAISE switch pressed operates relay $\frac{B1-P}{4}$.

(c) Relay $\frac{B1-P}{4}$ operated:

(i) self-holds across $\frac{B1-A}{4}$ contact,

(ii) prepares circuit to relay $\frac{B1-R}{3+2}$,

(iii) operates relay $\frac{B1-G}{2}$ (see also Section 6.1 (b) below).

(d) Relay $\frac{B1-G}{2}$ operated, operates relay $\frac{B1-TG}{2}$.

(e) Relay $\frac{B1-TG}{2}$ operated:

(i) releases relay $\frac{B1-A}{4}$ by contact B1-TG1,

(ii) prepares the circuit to relay $\frac{B1-R}{3+2}$ by contact B1-TG2.

(f) Relay $\frac{B1-A}{4}$ released:

(i) prepares circuit to relay $\frac{B1\text{-}R}{3+2}$,

(ii) releases relay $\frac{B1\text{-}G}{2}$ which in turn releases relay $\frac{B1\text{-}TG}{2}$.

(g) Relay $\frac{B1\text{-}TG}{2}$ releasing operates relay $\frac{B1\text{-}R}{3+2}$ via contacts B1-TG1 released and B1-TG2 delayed.

(h) Relay $\frac{B1\text{-}R}{3+2}$ operated:

(i) starts the RAISE motors,

(ii) self-holds across the RAISE switch operating contacts,

(iii) prevents re-operation of relay $\frac{B1\text{-}A}{4}$ by the back contacts of the RAISE switch.

(i) At the expiry of the time delay set by the adjustment of relay $\frac{B1\text{-}TG}{2}$, the contact B1-TG2 releases, breaking the circuit to relay $\frac{B1\text{-}R}{3+2}$.

(j) Relay $\frac{B1\text{-}R}{3+2}$ releasing:

(i) stops the RAISE motor,

(ii) re-operates relay $\frac{B1\text{-}A}{4}$,

(iii) releases relay $\frac{B1\text{-}P}{4}$.

The circuit is ready for the next RAISE switch operation.

5.5 RAISE Time Guard

The maximum time that relay $\frac{B1\text{-}R}{3+2}$ can remain energised is determined by the time delay of contact B1-TG2 of the timing relay $\frac{B1\text{-}TG}{2}$. This is set to give a maximum period of approximately 7 seconds, at the end of which the relay $\frac{B1\text{-}R}{3+2}$ is released and the drive to the control arms is stopped.

A STOP RAISE switch is installed in Panel 5 so that the drive upwards can be stopped at any time when the B1-TG2 contact is operated.

Each time that relay $\frac{B1\text{-}R}{3+2}$ is released, the RAISE switch must be re-operated to continue the raising of the arms.

6. MASTER GEARBOX AND CONTROL ARM POSITION INTERLOCKS

6.1 Master Gearbox Raised off Lower Limits

(a) Slow motors lower electrical limit switch B1-EL1 changes over at approximately 0.07° of control arm angle to provide a circuit to the switching relay $\frac{B1\text{-}K}{3+2}$ in parallel with that provided by the contacts of the control relay $\frac{B1\text{-}L}{3+2}$. Under control or safety circuit action

releasing relay $\frac{B1\text{-}L}{3+2}$, the SLOW DOWN motor will drive. The switching relay $\frac{B1\text{-}K}{3+2}$ is held energised over B1-EL1 to maintain the power supply to the motor.

(b) The lower electrical limit switch B1-EL2 changes over at approximately 0.27° of control arm angle to maintain the circuit for relay $\frac{B1\text{-}G}{2}$ over contacts of the Divergency Unit relay $\frac{SW\text{-}B}{8}$ (see AAEC/M7 for details of Divergency Unit relays).

(c) The fast motors lower electrical limit switches B1-EL3 and B1-EL4 change over at approximately 0.73° of control arm angle. They complete the circuits to the fast motors switching relays $\frac{B1\text{-}E1}{3+2}$ and $\frac{B1\text{-}E2}{3+2}$ so that power is available to the FAST DOWN motors should the control relays $\frac{B1\text{-}F1}{3+2}$ and $\frac{B1\text{-}F2}{3+2}$ be released in response to control or safety circuit action.

It will be noted that any condition releasing the control relays $\frac{B1\text{-}F1}{3+2}$ and $\frac{B1\text{-}F2}{3+2}$ causes the control relay $\frac{B1\text{-}L}{3+2}$ to be released also. This results in the FAST DOWN and SLOW DOWN motors running together. The effect of this is to reduce the run down time over the full range of movement from approximately 5.0 minutes with the FAST DOWN motors only, to approximately 4.2 minutes with both FAST DOWN and SLOW DOWN motors.

6.2 Control Arm Head Raised off Down Limits

The control arm head unit down limit switches $B1_n$-DL1 change over at approximately 1.5° of control arm angle. They comprise a CONTROL ARMS DOWN guard for pre-start-up and maintenance operations. With the control arms at 0° the switches are closed in series to energise relay $\frac{B1\text{-}D}{4}$ (see Figure 5).

(a) Control arms at 0°, relay $\frac{B1\text{-}D}{4}$ operated:

(i) disconnects CONTROL ARMS NOT DOWN lamp, panel 5 fault analysis panel shutdown display via its contacts 4, 5 and 6,

(ii) operates relay $\frac{BD\text{-}G}{8}$ for interlocks in Safety Rods, Dump Valve, No. 2 lockout switch (maintenance) circuits via its contacts 21, 22 and 23 (see AAEC/M9 for details),

(iii) prepares the circuit to relay $\frac{CR\text{-}G}{6}$ in the Start Guard circuit via its contacts 24, 25 and 26 (see AAEC/M7 for details),

(iv) contacts 1, 2, 3 are not used.

(b) Control arms above 1.5°, relay $\frac{B1\text{-}C}{6}$ operated:

Relay $\frac{B1\text{-}D}{4}$ is de-energised by the opening of the switches $B1_n$-DL1 in series. The CONTROL ARMS NOT DOWN lamp is kept extinguished by a contact of relay $\frac{B1\text{-}C}{6}$ during normal operation. When relay $\frac{B1\text{-}C}{6}$ releases under trip conditions, the CONTROL ARMS NOT DOWN lamp on the shutdown state display will be lit until all control arms reach the normal down position to re-energise relay $\frac{B1\text{-}D}{4}$.

The control arm head unit switches $B1_n$-DL2 also change over at approximately 1.5° of control arm angle. They are connected in series to control the relay $\frac{B1\text{-}DI}{6}$.

(a) In the shutdown state, relay $\frac{G\text{-}SC}{4}$ provides a circuit for relay $\frac{B1\text{-}DI}{6}$ to energise. During the starting sequence this circuit is transferred to a holding contact of relay $\frac{B1\text{-}DI}{6}$ and a contact of relay $\frac{G\text{-}TG}{4}$. At the expiry of the start time guard this holding circuit is broken when relay $\frac{G\text{-}TG}{4}$ releases, but by this time the control arms are at a higher angle than that marked by the settings of the switches $B1_n$-DL2. The circuit to relay $\frac{B1\text{-}DI}{6}$ is therefore transferred from the $\frac{G\text{-}TG}{4}$ contact to the B1-DL2 switches in series. (See AAEC/M7 for details of Start Guard circuit relay operation, and Figures 4 and 5 for the circuit to relay $\frac{B1\text{-}DI}{6}$.

(b) It will be noted that relay $\frac{B1\text{-}DI}{6}$ has two windings. One is connected as described above and the other via interlocking contacts to the + 50 volt d.c. supply controlled by relay $\frac{G\text{-}SC}{4}$ so that if relay $\frac{B1\text{-}DI}{6}$ releases, the changeover of the interlocking contact completes a holding circuit to the relays $\frac{B1n\text{-}M}{6}$ which are similarly arranged. Contacts of the TRIP and CONTROL REVERSAL guard relays $\frac{T\text{-}G1}{6}$ and $\frac{CR\text{-}G}{6}$ respectively are included in the holding circuit to prevent release of any of these relays under normal TRIP or CONTROL REVERSAL conditions.

With this arrangement, only the relay associated with the prime cause of the control arms release is disconnected.

(c) Relay $\frac{B1\text{-}DI}{6}$ has one spare springset; the remainder are used to:

(i) complete the circuit to the control relays $\frac{B1\text{-}Ba}{8}$, $\frac{B1\text{-}Bb}{8}$ (contacts 1, 2, 3);

(ii) disconnect the CONTROL ARMS DOWN LIMIT fault analysis lamp (contacts 7, 8, 9);

(iii) complete the circuit to relay $\frac{\text{B1-I}}{6}$ (contacts 21, 22, 23) (see Figure 5);

(iv) self-hold its own operating coil (contacts 24, 25, 26);

(v) prepare the circuit to its own holding coil (contacts 27, 28, 29).

The fault display provided by relay $\frac{\text{B1-DI}}{6}$ is maintained until the main control switch is turned OFF.

(d) Relay $\frac{\text{B1-I}}{6}$ energised:

(i) completes the circuit to the control relays $\frac{\text{B1-Ba}}{8}$, $\frac{\text{B1-Bb}}{8}$ (contacts 1, 2, 3);

(ii) disconnects the CONTROL ARMS annunciator lamps in panel 4 (contacts 7, 8, 9);

(iii) completes the circuit to relay $\frac{\text{CR-G}}{6}$ monitoring the CONTROL REVERSAL condition (contacts 24, 25, 26) (see AAEC/M7 for details);

(iv) completes a chain of contacts to the COMPLETE SHUTDOWN audible alarm relay $\frac{\text{X-WA}}{1}$ (contacts 27, 28, 29) (see AAEC/M23 for details).

6.3 Magnet Monitoring Relays

(a) The magnet monitoring relays $\frac{\text{B1}_n\text{-M}}{6}$ are energised initially by the operation of relay $\frac{\text{B1-RM}}{6}$. When relay $\frac{\text{G-SC}}{4}$ is energised during the start sequence, relay $\frac{\text{B1-RM}}{6}$ is released. If the polefaces and armatures of the control arm magnets are in contact, each relay $\frac{\text{B1}_n\text{-M}}{6}$ will remain energised in series with a holding contact and the microswitch B1_n-ME1 in the corresponding control arm head unit.

(b) Under operational conditions all control arms are released from their lifting magnets if:

(i) any TRIP condition operates to danger (by release of relays $\frac{\text{T-P1}}{8}$, $\frac{\text{T-P2}}{8}$, $\frac{\text{T-Y1}}{8}$ and $\frac{\text{T-Y2}}{8}$);

(ii) any one (or more) control arm drops off its lifting magnet;

(iii) any one (or more) control arm drops or is lowered to the normal down position where the switches B1_n-DL2 operate.

Condition (i) will result in the relay $\frac{\text{T-G1}}{6}$ releasing.

Condition (ii) will result in one (or more) of the relays $\frac{\text{B1}_n\text{-M}}{6}$ releasing.

Condition (iii) will result in relay Bl-DI releasing.

(c) All these relays have contacts in a series chain holding the control relays $\frac{Bl\text{-}Ba}{8}$, $\frac{Bl\text{-}Bb}{8}$ energised. Release of any one will therefore release the control relays which have contacts in each lifting magnet circuit, and all magnets are de-energised allowing the six control arms to fall to the fully-in position.

(d) The prime cause of the failure will be indicated by the operation of the circuit shown in Figure 4. The second windings of relays $\frac{Bl_n\text{-}M}{6}$ are interconnected in a similar manner to relay $\frac{Bl\text{-}DI}{6}$ to the + 50 volt d.c. supply controlled by relay $\frac{G\text{-}SC}{4}$ so that if any one relay releases, its contacts complete the holding circuit to all the remaining relays. Thus, in the situation where all control arms are dropped, if the trip is due to a particular control arm falling off its magnet, only the $\frac{Bl_n\text{-}M}{6}$ relay corresponding to that arm will be released.

(e) The contacts of relays $\frac{Bl_n\text{-}M}{6}$ are used to:

(i) complete the circuit to the control relays $\frac{Bl\text{-}Ba}{8}$, $\frac{Bl\text{-}Bb}{8}$ (contacts 1, 2, 3);

(ii) provide maintenance operation of the RAISE motor, provided that $\frac{Bl_n\text{-}M}{6}$ is operated (contacts 4, 5, 6);

(iii) indicate at the fault analysis panel CONTROL ARM OFF MAGNET (contacts 7, 8, 9);

(iv) complete the circuit to relay $\frac{Bl\text{-}I}{6}$ (contacts 21, 22, 23);

(v) holding circuit (contacts 24, 25, 26);

(vi) interconnect to its second coil (contacts 27, 28, 29).

6.4 Fault Indication

Under fault conditions which release any of the relays $\frac{Bl\text{-}DI}{6}$ or $\frac{Bl_n\text{-}M}{6}$, relay $\frac{Bl\text{-}I}{6}$ releases and:

(i) rings the TRIP alarm bell;

(ii) releases the relays $\frac{Bl\text{-}Ba}{8}$, $\frac{Bl\text{-}Bb}{8}$ and hence relay $\frac{Bl\text{-}C}{6}$; (the lifting magnets are de-energised and relay $\frac{Bl\text{-}C}{6}$ released starts the FAST DOWN and SLOW DOWN motors to return the master gearbox to the down limit position);

(iii) lights the CONTROL ARMS annunciator on Panel 4;

(iv) prevents re-starting of the reactor until the main control switch has been turned OFF to release relay $\frac{G\text{-}SC}{4}$ so that the magnet circuits can be re-established. Turning the main control switch OFF extinguishes the CONTROL ARMS DOWN LIMIT lamp.

The fault display provided by relays $\frac{Bln\text{-}M}{6}$ is maintained until the control arms are again brought into contact with their lifting magnets.

6.5 Control Arms Up Limits

These are the microswitches Bl_n-UL1 and Bl_n-UL2 in the head units, operated when the arms reach approximately 55.5°. Switches Bl_n-UL1 are connected in series in the primary CONTROL REVERSAL guard line, and switches Bl_n-UL2 in series to operate the CONTROL REVERSAL secondary guard relay $\frac{Bl\text{-}Z2}{6}$ which has contacts 1, 2 and 3 in the Secondary CONTROL REVERSAL Guard line. Operation of the up limit switches therefore initiates a fast run down of the control arms (see AAEC/M4 for details of CONTROL REVERSAL circuits).

6.6 Control Arm Position Indication

(i) Coarse and fine indications of control arm position are presented on Panel 5 by receiver synchros driven from transmitter synchros in the master gearbox. The coarse display is calibrated in steps of 1° between 0 and 56° representing the full normal travel of the arms. The fine indicator revolves once for each degree of movement and is calibrated in 0.01° steps.

(ii) A 100 ohm helical potentiometer is also driven by the master gearbox and is connected to the control arm position recorder in Panel 4 to provide a continuous record of control arm angle.

6.7 Master Gearbox RAISE Motor Upper Limit Switch

This switch, Bl-EL5, is connected directly in the circuit of relay $\frac{Bl\text{-}R}{3+2}$ so that when the master gearbox reaches its upper electrical limit where the switch is operated, relay $\frac{Bl\text{-}R}{3+2}$ is disconnected and further upward movement is prevented. Normally the up limit switches in the control arm heads will bring about a CONTROL REVERSAL before the master gearbox reaches the setting of Bl-EL5 which is at approximately 55.8°.

7. DOWNWARD DRIVE

7.1 SLOW DOWN Drive

The master gearbox must be above the setting of Bl-EL1 for the SLOW DOWN motor to operate. This requirement is to maintain the SLOW DOWN motor switching

relay $\frac{B1-K}{3+2}$ energised when the control relay $\frac{B1-L}{3+2}$ is released.

Any condition which releases relay $\frac{B1-L}{3+2}$ starts the SLOW DOWN motor, and the downward drive will continue until either relay $\frac{B1-L}{3+2}$ is re-operated or relay $\frac{B1-K}{3+2}$ is released.

Under normal conditions of operation the control arms are run down slowly by operation of the SLOW DOWN switch on Panel 5. This releases relay $\frac{B1-L}{3+2}$ while the switch is held operated. On releasing the switch, the relay will normally re-operate to stop the motor, unless the master gearbox has been driven to the SLOW MOTORS LOWER ELECTRICAL LIMIT (switch B1-EL1, set at 0°) when the relay $\frac{B1-K}{3+2}$ will release to switch off the motor.

Note that any condition which starts the FAST DOWN motors ($\frac{B1-E1}{3+2}$ or $\frac{B1-E2}{3+2}$ operated and $\frac{B1-F1}{3+2}$ or $\frac{B1-F2}{3+2}$ released) will release relay $\frac{B1-L}{3+2}$ and automatically start the SLOW DOWN motor.

7.2 FAST DOWN Drive

The master gearbox must be above the setting of the switches B1-EL3 and B1-EL4 for the fast down motors to operate. This maintains the switching relays $\frac{B1-E1}{3+2}$ and $\frac{B1-E2}{3+2}$ energised while the control relays $\frac{B1-F1}{3+2}$ and $\frac{B1-F2}{3+2}$ are released.

The control relays $\frac{B1-F1}{3+2}$ and $\frac{B1-F2}{3+2}$ are released to start the fast motors if:

(a) The FAST DOWN toggle switch on Panel 5 is operated.

(b) The main control switch is turned OFF.

(c) No. 2 lockout switch is moved off the OPERATIONAL position.

(d) The master switch is moved off the HOLD position.

(e) Any CONTROL REVERSAL guard operates to danger thereby releasing the relays $\frac{CR-P1}{8}$, $\frac{CR-P2}{8}$, $\frac{CR-Y1}{8}$ and $\frac{CR-Y2}{8}$, and in turn relay $\frac{CR-G}{6}$.

(f) Any TRIP condition releases the control arms from their lifting magnets releasing relay $\frac{B1-C}{6}$.

8. MISALIGNMENT OF THE SELSYN TRANSMISSION SYSTEM

8.1 Coincidence Synchros (See AAEC/M30 for other details)

The position of the master gearbox transmitter selsyn is compared with that of the receiver selsyn in the slave gearboxes by a system of coincidence synchros. A transmitter synchro in the master gearbox has its rotor energised

by a 24 volt single phase alternating voltage. Its three phase stator winding is connected to the stators of the six slave gearbox coincidence synchros in parallel. The rotors of the coincidence synchros are adjusted at zero misalignment to provide an output voltage of approximately 0.1 volts peak-to-peak which will not operate the misalignment indicator. At a misalignment of 1 minute of arc (actually 1.5° of synchro shaft rotation) the output signal from any coincidence synchro is approximately 1.0 volt peak-to-peak and trips the misalignment indicator corresponding to the particular control arm.

8.2 Misalignment Indicators Type 1511A (see Figure 6)

Two of these units are installed as units 1 and 2 in Control Room Panel 3. Each contains one spare and three active plug-in indicators which have duplicated electronic switches. Each active plug-in indicator monitors the signal from one of the slave gearbox coincidence synchros. The fault signal is used to cut off a gasfilled electron tube which normally holds a relay energised. When the tube is cut off, the relay releases, initiating a TRIP signal. Both 'poles' of the switch must operate, and both relays release to initiate the TRIP. Each pole can be tested by a switch on the indicator which applies a test signal to the input. This can be done if the other pole of the switch has not operated or failed to the TRIP condition.

9. MAINTENANCE FACILITIES

9.1 General

Service switches, operated by key HIFAR No. 3 are located:

(i) In Control Room Panel 2 (B1Q-1A and B1Q-1B);

(ii) In reactor gallery level above Face 3 adjacent to the bank of three slave gearboxes (B1Q-2A and B1Q-2B).

Key HIFAR 3 is trapped in No. 2 lockout switch in the OPERATIONAL position. For maintenance purposes, this switch can be turned to four positions other than OPERATIONAL when the key is released to be used in service units associated with the section of plant selected by the switch position, viz. SAFETY RODS, DUMP VALVE, COARSE CONTROL ARMS and FINE CONTROL ROD.

In the COARSE CONTROL ARMS position, the key may be used directly in the service switches in Panel 2 or at the gallery level to operate the master gearbox drive and control arm head mechanisms with the lifting magnets de-energised. Alternatively, an individual arm may be selected by switch B1QS in the lockout bypass panel, and then the key may be used in the service switches. Under these

conditions all mechanisms are driven by the master gearbox, but only the lifting magnet of the selected arm is energised (see Figures 1 and 3).

The corresponding switches in the two service locations are interconnected so that the system can be operated from either position.

Switches B1Q-1A and B1Q-2A control the RAISE and SLOW DOWN motors. Switches B1Q-1B and B1Q-2B provide FAST DOWN and DROP (that is, magnet released) conditions as required.

9.2 Conditions Required for Maintenance Operation

(a) For the transmission system only:

(i) The master switch must be in the HOLD position. This implies that the safety rods will be raised, but since no lifting magnets are to be energised, no positive interlock on this condition is included.

(ii) The main control switch must be turned OFF.

(iii) No. 2 lockout switch must be turned to position 4, COARSE CONTROL ARMS.

Key 3 is then removed from the lockout switch and used to control the service switches.

(b) For an individual control arm:

(i) Conditions in Section 9.2 (a) above are required.

(ii) Key 3 is used to set the maintenance selector switch B1QS to select the particular control arm required to be operated.

(iii) Both safety rods must be raised. This is positively interlocked by contacts 1 and 2 of relay $\frac{B3\text{-}G}{4}$.

10. DROP TESTING

The timing of the fall of a control arm is enabled by the provision of:

(a) A pulse transformer in the lifting magnet circuit which provides an output pulse when the magnet coil is de-energised.

(b) An additional magnet pole face switch $B1_n$-ME2 in each control arm head unit which provides a step change in signal level when the control arm magnet and armature separate.

(c) An additional down limit switch $B1_n$-DL3 in each control arm head unit

which provides a step change in a signal level of opposite sign to that in (b) above when the control arm reaches the down limit setting. These signals are amplified and displayed to provide a measure of:

(i) the time delay between the magnet current interruption and the armature separating from the lifting magnet;

(ii) the time of the drop, measured from the instant the magnet and armature separate to the instant the control arm operates the down limit switches.

Drop testing can be carried out either on a single arm or on the ganged bank under appropriate conditions.

11. REFERENCES

Page, G. (1959). - Reactor HIFAR: An Introduction to the Guard and Safety Circuits, AAEC/M1.

Sinclair, W. J. (1968). - Reactor HIFAR: The Coarse Control System. AAEC/M30.

APPENDIX 1

DESCRIPTION OF RELAY $\frac{\text{B1-TG}}{2}$

The timing relay is a standard Electro Methods Ltd., type 500/25 pneumatic time delay, in which the pneumatic system is actuated by a solenoid. It consists of a spring loaded bellows of synthetic rubber fitted with an adjustable valve for controlling the rate of expansion. When the solenoid is energised the bellows are compressed immediately, and then on disconnecting the solenoid, they expand under the spring tension at a rate determined by the valve. The relay is fitted with two sets of contacts, one B1-TG1 showing when the solenoid is operated (that is, when the bellows are fully compressed), and the other B1-TG2 marking the time delay interval by remaining closed while the bellows are off the normal condition. The time range is adjustable from 0.25 seconds to 3.0 minutes. For $\frac{\text{B1-TG}}{2}$ this is adjusted to approximately 7 seconds.

APPENDIX 2

REACTOR HIFAR - LIST OF INSTRUMENTATION MANUALS

The status of titles that have not been issued at March 1970 is indicated by the following marks:

* In draft

★ Not yet issued

■ Title and serial number cancelled

	M 1	Introduction to HIFAR Guard and Safety Circuits
	M 2	Complete Shutdown Circuits
	M 3	Trip Circuits
	M 4	Control Reversal Circuits
	M 5	Warning Circuits
*	M 6	Primary Search Unit
	M 7	Start Guard Circuits
★	M 8	Flux Trip Circuits
*	M 9	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 a.c., 50V d.c., 240V a.c., 4-LLA-10, 4-L-15, 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
■	M31	The Fine Control System
*	M32	The Safety System
■	M33	Fine Control Drive System
	M34	Leak Detectors
★	M35	Modifications for Low Power Operation
★	M36	Recorders
	M37	Physical Instrumentation of HIFAR
★	M38	Ionisation Chambers and Health Monitors
	M39	Test Schedule for Guard, Safety, and Interlock Circuits

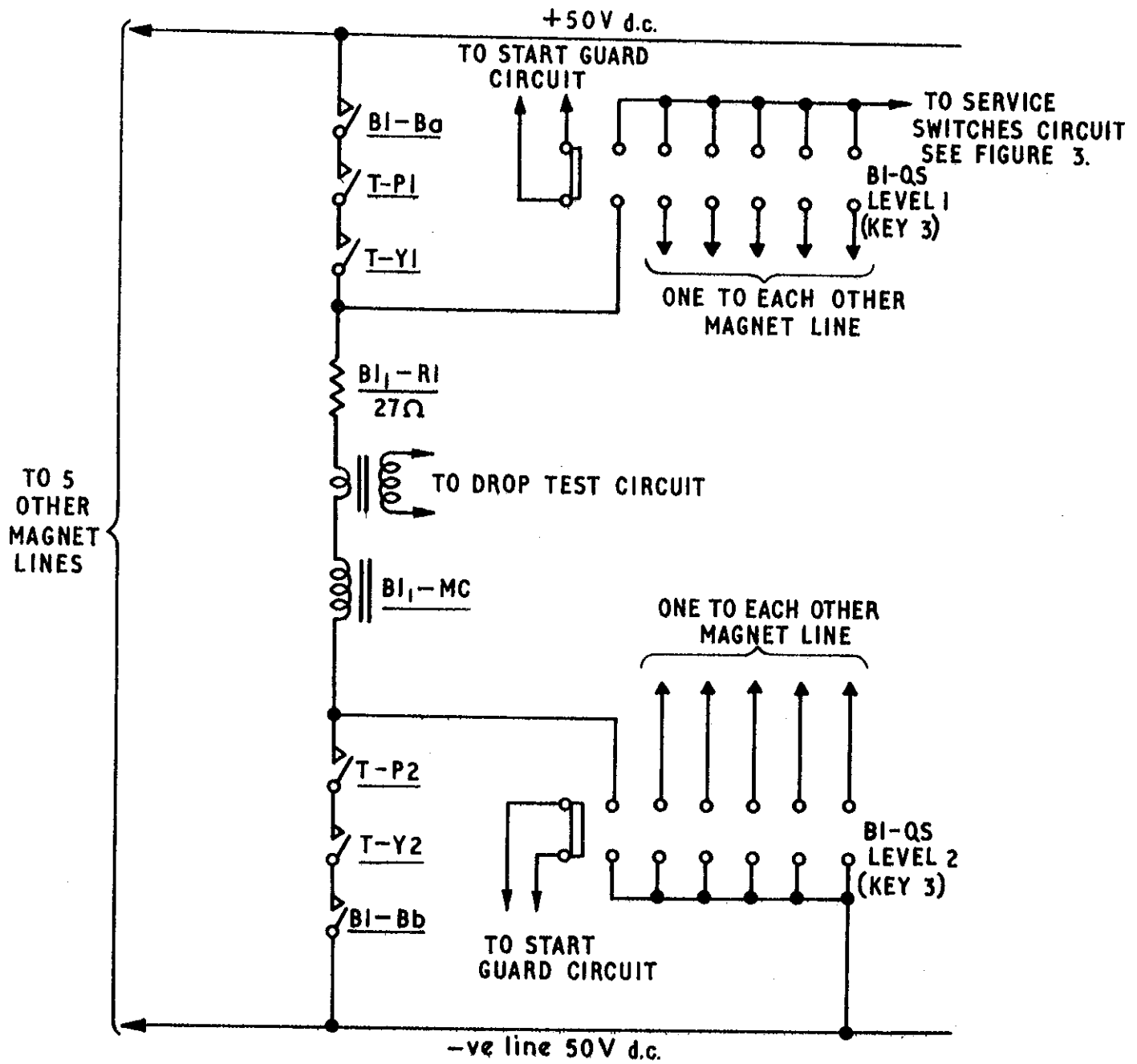

FIGURE 1. HIFAR – CONTROL ARM LIFTING MAGNET CIRCUIT
(From Drawing BE3967)

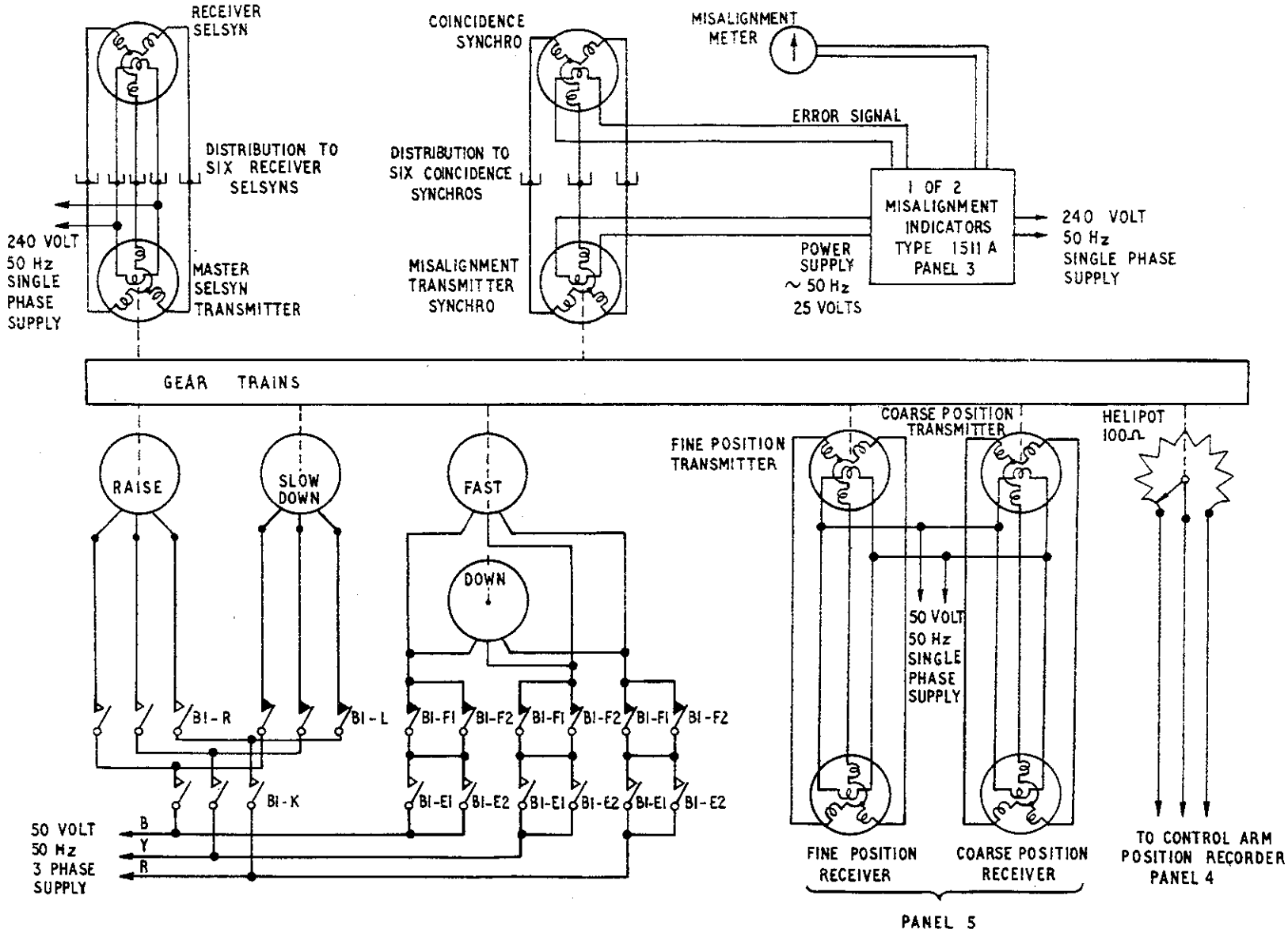

FIGURE 2. HIFAR — CONTROL ARM DRIVE MOTOR CIRCUITS AND POSITION INDICATORS
(From Drawing BE3914)

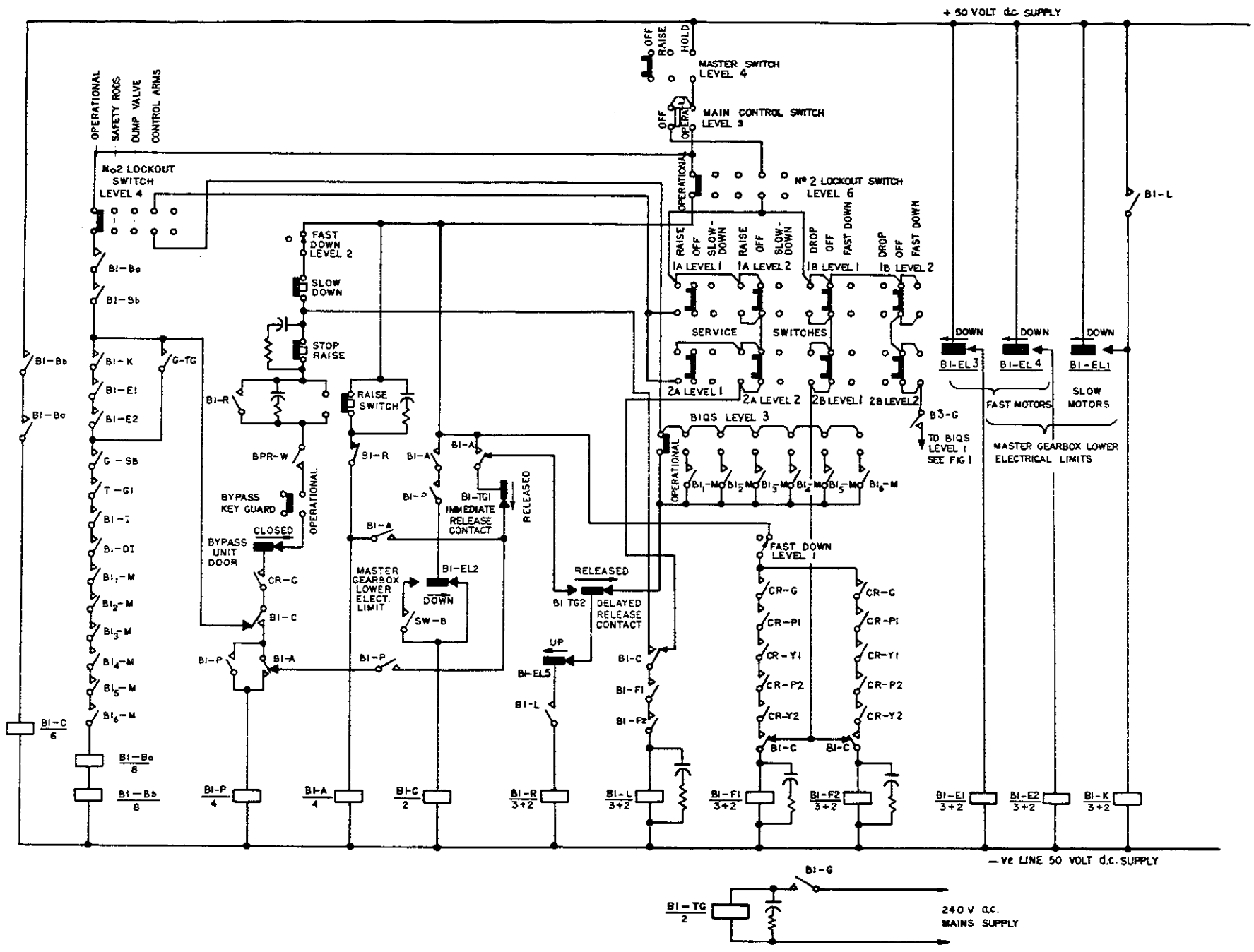

FIGURE 3. HIFAR — CONTROL ARM CIRCUIT (From Drawing BE3886)

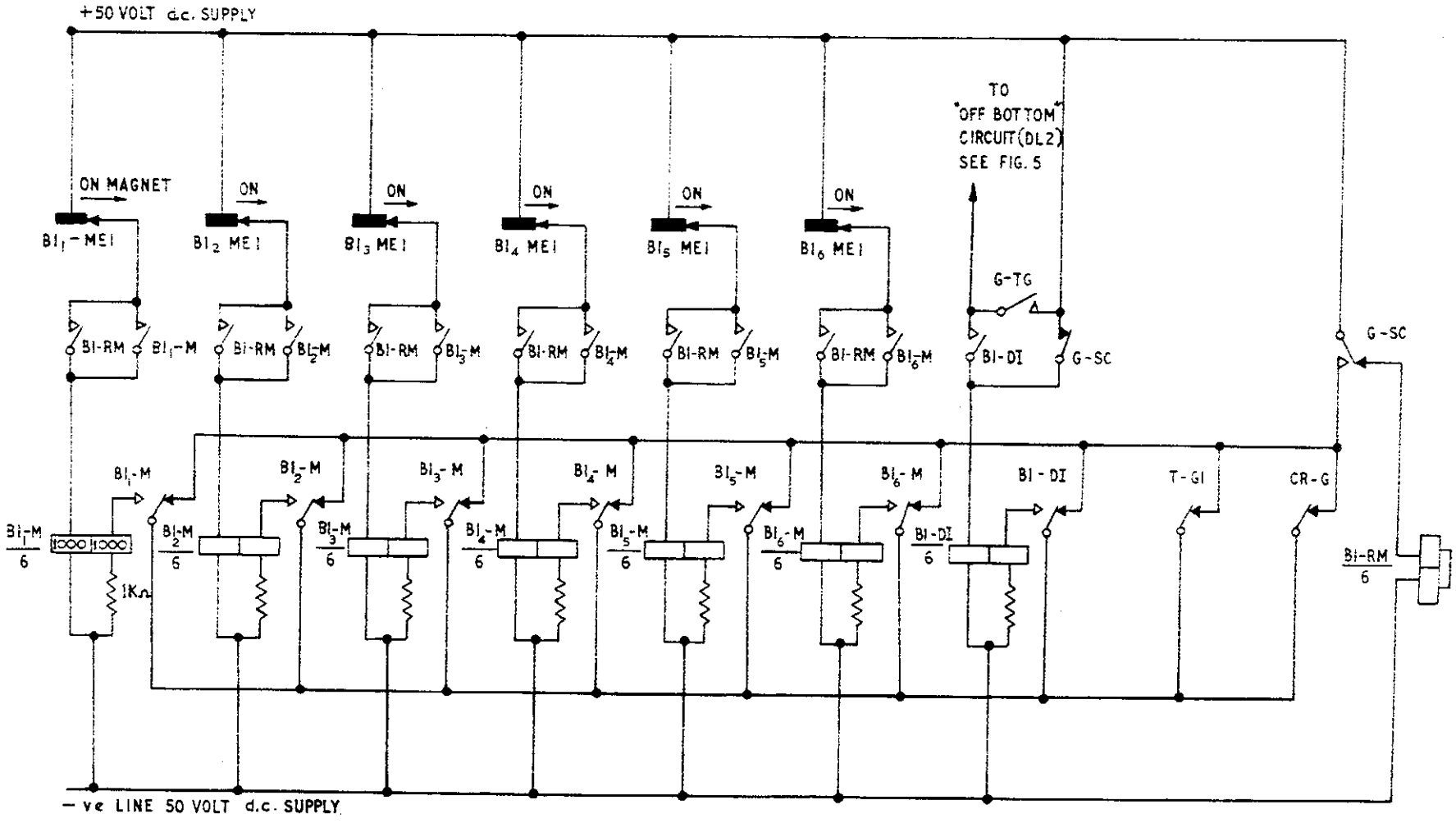

FIGURE 4. HIFAR — CONTROL ARMS POSITION INTERLOCK CONTROL (From Drawing BE3999)

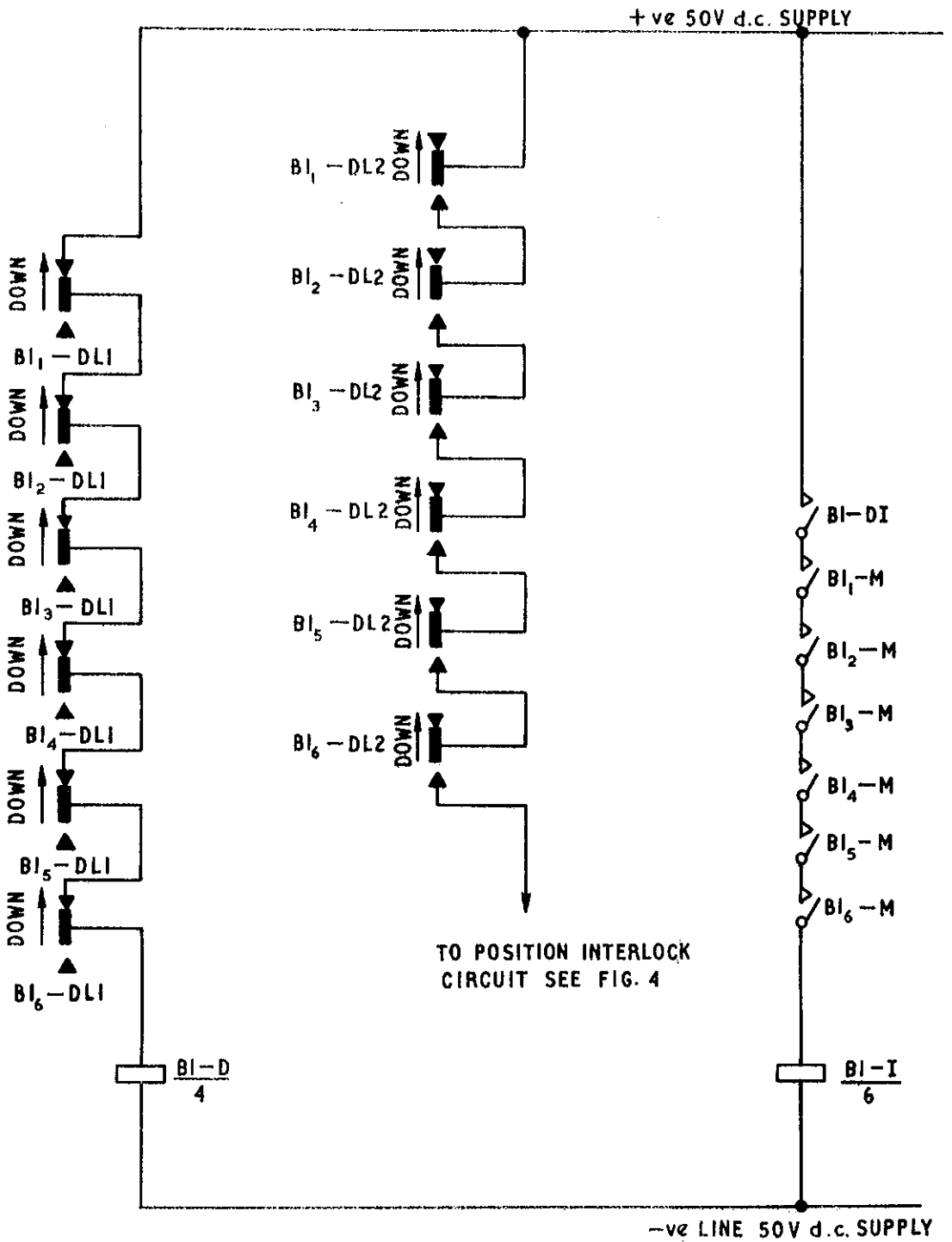

FIGURE 5. HIFAR — CONTROL ARMS DOWN GUARD AND POSITION INTERLOCK CIRCUITS (From Drawing BE3966)

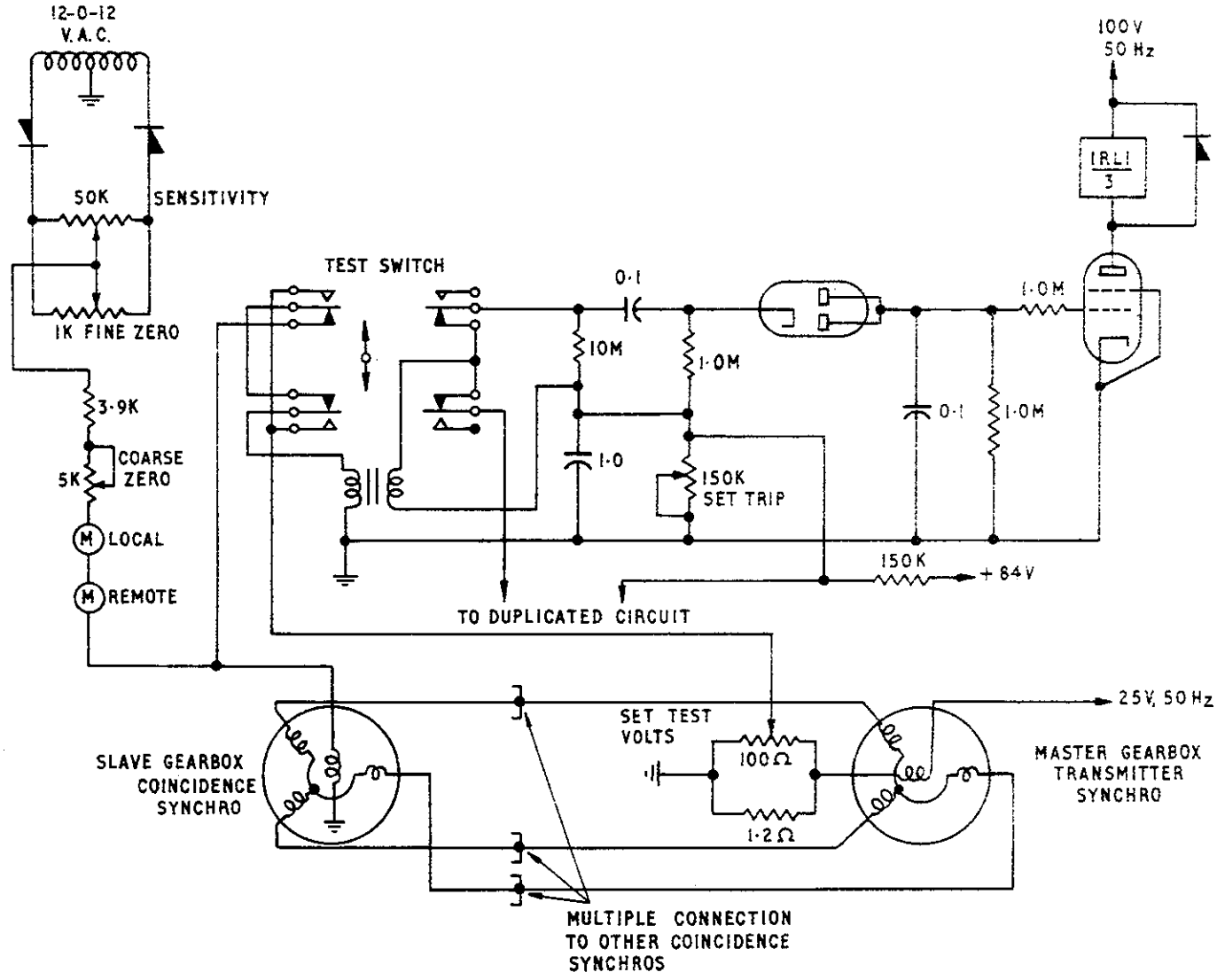

FIGURE 6. FIGURE 6. HIFAR — CONTROL ARMS MISALIGNMENT INDICATOR
(From Drawing P1558)