

THE HOUSE EXCHANGE SYSTEM No. 3 (KEYMASTER)

Circuit Operation

1. This Instruction describes the circuit operation of the House Exchange System (H.E.S.) No. 3. The facilities provided by this equipment are detailed in Q 1011 which also contains definitions of the terms used in the following paragraphs.

The diagrams quoted in paragraph headings illustrate the circuit element to be described but it may be helpful to refer also to Dgms. SA 9174 and SA 9175 which show complete installations, and to Dgm Q(L) 403 which explains the codes allocated to various multiple conductors.

INTERCOM CALLS

2. *Seizing the intercom circuit* [Dgms. Q(L) 433 and 434].—Removing the handset operates CS springs.

CS1 (operated) changes over the incoming signal wire at the calling station to the common multiple wire.

CS2 connects the telephone loop via KX1 and KX2 to the intercom circuit operating relay IL in Relay-unit Q 405. (Relay-unit Q 410 is provided in lieu of Q 405 where a non-multiple extension is fitted.)

IL1 operated in Relay-unit Q 405 (or IL3 in Relay-unit Q 410) extends an earth over the L wire in the multiple to cause the intercom circuit supervisory lamps at all multiple stations to glow.

Depressing the calling button for the required station operates the appropriate KR springs. KR1 extends an earth to the buzzer wire of the called station and KR2 completes the connexion of the calling station buzzer to the common wire.

3. *Called station free.*—The earth on the buzzer wire operates the buzzer at the called station via CS1 at that station. When the called station answers the CS springs are operated. CS1 disconnects the buzzer and connects the signalling wire to the common wire. CS2 operated connects the telephone speech circuit to the intercom circuit via KX1 and KX2.

Both stations are now connected in parallel with the intercom circuit to which battery and earth are fed via the transmission bridge formed by the coils of relay IL.

4. *Called station engaged on an exchange call.*—If a multiple station is engaged the CS1 springs will be operated so connecting the incoming signal wire to the common wire. When called by another station the calling earth signal is extended over the signalling wire via CS1 operated, the common wire and KR2 (operated) at the calling station where the buzzer operates to indicate that the called station is engaged.

5. *Release of connexion.*—When both stations clear from the intercom circuit relay IL releases. IL1 (or IL3) removes the earth from the intercom lamp circuit so that the lamps cease to glow.

6. *Multiple station calling non-multiple extension* [Dgms. Q(L) 410, 420, 433 and 434].—When the calling station presses the signalling button for the non-multiple extension an earth is extended via KR1 operated, the signal wire, to terminal 17 on Relay-unit Q 410.

7. *Non-multiple extension free.*—The incoming earth signal at terminal 17 (Relay-unit Q 410) operates relay RR via A3, EX4 operated and RC7; relay EX in Relay-unit Q 410 is normally operated except during an exchange line call. RR2 and RR3, operated, apply 25 c/s ringing current, obtained from a Converter, Ringing, No. 7, to the non-multiple extension telephone.

8. *Non-multiple extension answers.*—To answer an incoming call the handset is lifted and the EXTN button pressed; this operates KM springs in the telephone and completes the loop across the extension line. When relay RR restores, the telephone loop is extended via RR2, RR3, relay D coils, EX1 and EX2 operated, to operate relay A. (Relay D is differentially connected and does not operate at this stage.) A3 applies station engaged conditions to the common wire, and A6 completes a locking circuit for relay IL. Transmitter current for the non-multiple extension is fed via the two 200-ohm windings of relay A, and the speech between the non-multiple extension and multiple station is via the transmission bridge formed by capacitors C4 and C5. R4 is a 'wetting' resistor for contacts B2 and B5. Relay IL coils supply transmitter current to the intercom circuit (see par. 3).

9. *Non-multiple extension engaged.*—If the non-multiple extension is engaged on an exchange call relay EX will not be operated. The incoming signal earth on the buzzer wire will then be extended via A3 and EX4 to the common wire and so back to the calling station where it will operate the buzzer (see par. 4). If the non-multiple extension is engaged on the intercom circuit and is called by a multiple station which has ignored the intercom engaged lamp, the calling station buzzer is operated over the circuit just described, via A3 operated.

10. *Release of connexion.*—If the multiple station clears first at the end of an intercom call, the telephone loop is removed but relay IL remains operated due to the loop formed by IL1 and A6, both operated, and R3. This locking circuit on relay IL prevents the earth at D1 being extended via IL2, B6 and A5 operated to give a false call at the main station buzzer. When the non-multiple extension clears relay A releases and A6 removes the holding loop from relay IL which releases.

**11. Non-multiple extension calling a multiple station [Dgm. Q(L) 434].**—The handset is lifted and the EXTN button pressed so operating the KM springs and completing the telephone loop. The loop operates relay A via RR2, RR3, relay D coils, EX1 and EX2 ; relay D does not operate. A signalling earth is applied to the main station buzzer wire via D1, IL2, B6 and A5 operated. A4 operates to cause the intercom supervisory lamps to glow. If the main station is free the earth signal operates the main station buzzer. The interruptions of current by the buzzer contacts develop a pulsing potential across resistor R2. The pulses are applied to the 570-ohm winding of relay A via C6 and, by a transformer action between the windings of this relay, they are heard as a tone at the non-multiple extension giving verification that the main is being called.

When the main station answers, its telephone loop operates relay IL. IL2 disconnects the calling signal and IL1 completes the locking circuit for relay IL (see par. 10). The main station is requested to signal the required station and when it answers the transmission circuit described in par. 8 is completed.

If the main station is engaged on an exchange call when the non-multiple extension calls, buzzer tone is not heard as the buzzer circuit is interrupted by CS1 at the main.

If the intercom circuit is in use when the non-multiple extension tries to call the main station, the conversation taking place will be overheard.

**12. Conference call.**—A multiple station may set up a conference call by signalling each of the required stations in turn as described in pars. 2 and 3. When the called stations answer they are all connected in parallel with the intercom circuit. The non-multiple extension may be included in a conference call ; it is signalled as described in par. 6 and the speech circuit is described in par. 8.

**13. Release of conference connexion.**—If multiple stations only have participated, relay IL releases when all stations have cleared, but if the non-multiple extension has been included in the conference, relay IL will be held until all multiple stations and the non-multiple extension have cleared (see par. 10).

#### EXCHANGE CALLS

**14. Exchange line circuit.**—Dgm. Q(L) 431 shows how the exchange line is wired in a series circuit, entering the multiple at one end and proceeding into and out of each multiple station until the last station. Operation of the EXCH button at a multiple station disconnects the exchange line multiple from other stations beyond. This arrangement gives a degree of secrecy on exchange calls but users of the H.E.S. No. 3 should not press the EXCH button if the red supervisory lamp is glowing steadily. To prevent accidental interruption of the exchange line circuit a rocker-bar controlled by the gravity-switch plungers is fitted underneath the EXCH button. This device prevents a depression of the EXCH button until the handset is lifted.

**15. Multiple station calling exchange [Dgms. Q(L), 422, 431 and 432].**—When the handset is lifted and the EXCH button pressed KX and KH key contacts are operated.

KX1 and KX2 disconnect the speech circuit of the telephone from the intercom circuit and connect it to the exchange line. KX3 applies an earth which causes the exchange line engaged lamps to glow. KX4 disconnects resistor R3.

KH1 and KH3 disconnect the exchange line from other stations beyond the user station and also interrupt the series circuit of magneto bells. The exchange call proceeds in the usual way.

**16. Release of exchange connexion.**—At the end of the call the handset is replaced. The restoration of the gravity-switch causes the latch plate to release the KX and KH contacts and restore the circuit to normal.

**17. Non-multiple extension calling exchange [Dgms. Q(L) 410, 420, 431 and 434].** The handset is lifted and the EXCH button pressed. Due to a mechanical linkage between the exchange and extension plungers, the contacts associated with both buttons are operated by depression of the EXCH button thus completing the telephone loop and applying an earth to the B wire of the non-multiple extension line. This earth operates the differentially-connected relay D while the loop operates relay A.

Relay EX is normally operated to an earth at D1 (normal) via B3. When relay D operates, the earth at D1 is applied via EX 5 (operated) to maintain relay EX ; this earth also operates relay B via S1. B1 completes a loop, via EX 3 (operated), R1 and the coils of relay S, which seizes the exchange line. Exchange line current operates relay S. B2 and B5 disconnect the non-multiple extension from the intercom circuit. B3 prepares a locking circuit for relay B. B4 operates relay FL. B6 disconnects the buzzer signalling circuit to the main station.

When relay S operates, its contact completes an alternative holding circuit for relay B to the earth at RC3. FL1 causes the exchange line engaged lamps to glow. FL2 disconnects the bell circuit from the exchange line. A3, operated, applies station engaged condition to the common wire.

[NOTE :—A4 applies an earth to the intercom lamps while the EXCH button is pressed, but there is no interference with the intercom speech circuit if it is engaged.]

The circuit of Relay-unit Q 410 has now been prepared to connect the non-multiple extension to the exchange line. When the EXCH button of the non-multiple extension telephone restores, the contacts associated with the EXTN button remain operated because the latch plate holds the plunger down. Removal of the earth from the B wire releases relay D. Relay EX has been held by the earth at D1 since the operation of relay B. The restoration of relay D releases EX. MR2 prevents false operation of

the main station buzzer by the earth at D1 (operated) during the operating time of relay B.

EX1 and EX2 switch the extension line to the exchange line and release relay A. EX3 breaks the loop which seized the exchange line. EX4 and A3, both now normal, maintain the station engaged condition on the common wire. EX5 has no function at this stage.

During dialling relay S pulses but relay B remains operated.

**18. Release of connexion.**—When the non-multiple extension clears, the exchange line loop is disconnected and relay S releases. S1 releases relay B.

B3 restores D1 earth to reoperate relay EX, and B4 releases relay FL. FL1 removes earth from the exchange line supervisory lamps and FL2 restores the magneto bell circuit. EX4 operating removes the 'station engaged' condition.

**19. Exchange line engaged.**—When engaged by a multiple station the exchange line is diverted to that station and is disconnected from all stations in the multiple beyond the user station. Should the non-multiple extension lift the handset and press the EXCH button the A, B and D relays of the Relay-unit Q 410 operate as described in par. 17 but, if the exchange line is already in use, relay S will not operate and the sequence of relay operation is interrupted at this stage. If neither dial tone nor an answer is received from the exchange, the non-multiple extension should assume that the line is engaged, but may check by calling the main station where the exchange line supervisory lamp will be glowing.

**20. Incoming exchange calls; a.c. bell circuit [Dgm. Q(L) 431].**—Each Telephone, Intercom., No. 3/1 includes a magneto bell and key contacts (KB) which can normally be operated by the BELL-OFF button to short-circuit the bell. KB1, in series with the strap between telephone terminals T16 and T17, completes the short-circuit across the terminals T4 and T16 to which the bell is connected. At the main station the T16-T17 strap is removed to ensure that the bell there always rings on incoming exchange calls.

Multiple station magneto bells are connected in a series circuit which includes a 2  $\mu$ F capacitor and the ringing relay (relay RG) which are in the Relay-unit Q 405 or Q 410. In the relay-unit the bell circuit is connected to the B wire of the exchange line and at the opposite end of the multiple a strap in the Block, Terminal, No. 37A connects the other end of the bell circuit to the exchange line A wire.

**21. Answering an exchange call [Dgms. Q(L) 431 and 432].**—Relay RG is operated by ringing current. RG1 lights the exchange line supervisory lamps in rhythm with the ringing current. If a multiple station answers, the circuit conditions described in par. 15 are established. If the non-multiple extension

answers, operation of the EXCH button establishes the conditions described in par. 17 and these connect this extension to the exchange line.

**22. Night service at the non-multiple extension [Dgm. Q(L) 432].**—The non-multiple extension normally only receives incoming exchange calls directly when night service conditions are applied from the main station (but see also par. 32). At the main station the BELL-OFF button is replaced by one engraved N.S. [see Dgm. Q(L) 430]. This button operates the KB contacts. KB2 applies an earth to the NS wire in the multiple via terminal 25 in the telephone. The NS wire is connected to terminal 19 of Relay-unit Q 410. When exchange ringing current operates relay RG, contact RG2 extends the earth from terminal 19, via A3 and EX4 operated, to operate relay RR. RR2 and RR3 apply 25 c/s ringing current to the non-multiple extension.

**23. Multiple station holding the exchange line [Dgms. Q(L) 422 and 432].**—A multiple station may wish to hold an exchange call and speak to another station on the intercom circuit. Pressing the calling button for the required station causes the latch plate to release the KX contacts leaving only the KH contacts locked down. KX4 released and KH1 operated provide a 200-ohm hold loop (R3) across the exchange line. KX1 and KX2 switch the station instrument over to the intercom circuit. KX3 and KH2 (operated) extend an earth via telephone terminal 20, the D wire in the multiple, terminal 7 in Relay-unit Q 405 or Q 410 and contact FL1 (FL3 in Q 410) to operate relay FL which begins to pulse. FL2 (FL1 in Q 410) applies a pulsing earth to flash the exchange line supervisory lamps via the C wire.

**24. Non-multiple extension holding the exchange line [Dgms. Q(L) 410, 431 and 432].**—At the non-multiple extension an exchange call can be held while an intercom call to the main station is made. When the non-multiple extension is connected to the exchange line, relays B, FL and S in Relay-unit Q 410 are operated as described in par. 17. Re-pressing the EXCH button applies an earth to the B wire to operate relay D, in series with relay S and the exchange battery. The earth at D1, applied via EX5, operates relay RC. RC1 prepares a holding circuit for relay RC. RC3 releases relay B. RC4 causes relay FL to start pulsing when B4 restores (see par. 25). RC5 connects the 200-ohm resistor R1 across the exchange line as a holding loop and keeps relay S operated. RC6 disconnects the bell circuit from the line while relay FL is pulsing. RC7 prevents the operation of relay RR by an incoming intercom calling signal during this sequence; if relay RR was allowed to operate at this stage, the operation of relay A would be prevented and the exchange call might be lost. [NOTE :—Contact RC2 is spare and appears only in earlier versions of Relay-unit Q 410.]

When the EXCH button at the non-multiple extension

sion is released, relay D releases. Earth at D1, extended via B3, operates relay EX. EX1 and EX2 connect the non-multiple extension loop across relay A which operates. A1 completes a holding circuit for relay RC via RC1 (operated), B3 and D1. The functions of other contacts of relay A are described in par. 11. A speech circuit to the main station is completed via contacts B2, B5 and the intercom circuit. The exchange line is held and the supervisory lamps flash until the non-multiple extension re-enters the exchange line by reoperating the EXCH button. Relay D operates again. D1 breaks the holding circuit of relay RC which begins to release. During the delayed release, relay B operates via S1 operated, RC3 still operated, EX5 operated, to earth at D1. Relay EX remains operated for the time being. RC5 breaks the main holding loop across the exchange line, but there is a temporary alternative loop via B1 operated and EX3 operated. B4 in operating stops the pulsing of relay FL which now operates fully over the 1000-ohm coil. FL1 applies a constant earth to the exchange line supervisory lamps which now glow steadily to show that the exchange line has been re-engaged. Other contacts of relay B function as described in par. 17.

The release of the EXCH button releases relay D. D1 breaks the circuit which has been holding relay EX via EX5 operated. Other contacts of relay EX function as described in par. 17.

**25. Relay FL pulsing circuit in Relay-unit Q 405 [Dgms. Q(L) 405, 410 and 432].**—The pulsing circuit in Relay-unit Q 410 uses similar principles to Relay-unit Q 405 but the designations of circuit elements are different.

The coils of relay FL are differentially connected. The earth which the holding telephone (see par. 23) is sending to the relay-unit is applied, via FL1, to both coils of relay FL. Capacitor C1 discharges through the 2000-ohm coil, delaying the operation of the relay by the current in the 1000-ohm coil until the discharge current reduces sufficiently. When the relay operates, FL1 cuts off the earth. C1 begins to recharge through both relay coils in series; the charging current delays the release of the relay until C1 is almost fully charged. When the relay releases FL1 reconnects the earth to the relay coils and the cycle is repeated. The pulsing rate is 2-3 p.p.s.

#### TRANSFER OF EXCHANGE CALLS

**26. Transfer from one multiple station to another [Dgms. Q(L) 431 and 432].**—As a preliminary to the transfer of an exchange call, the exchange line will be 'held.' The circuit conditions described in pars. 23 and 25 will have been established and the exchange line supervisory lamps will be flashing.

When the station accepting the call presses the EXCH button contacts KX1 and KX2 prepare the speech circuit (see par. 15). KX3 applies an earth to the C wire, by-passing the pulsing earth due to the FL contact in the relay-unit. The exchange line supervisory lamps now glow steadily, indicating

to the transferring station that the accepting station is ready to take over the call. Depending on the relative positions of the two stations in the multiple, the transfer of the exchange call may not be completed until the transferring station replaces its handset (see par. 14). When this occurs KX3 removes the earth which has been operating relay FL via the D wire. KX4 disconnects resistor R3 from the exchange line.

**27. Transfer from a multiple station to the non-multiple extension [Dgms. Q(L) 410, 420 and 434].**—As a preliminary to the transfer of an exchange call, the multiple station will hold the call as described in par. 23 and at the same time will signal the non-multiple extension as described in par. 7. Relay IL is operated; relay FL is pulsing.

The non-multiple extension responds by operating the EXTN button which establishes the circuit conditions described in par. 8.

When the non-multiple extension wishes to take over the exchange line the EXCH button is operated and so operates relay D. Earth at D1 is extended via EX5 operated to hold relay EX and via S1 to operate relay B. B1, EX3 and R1 in Relay-unit Q 410 provide an alternative holding loop across the exchange line to guard against premature clearing of the holding multiple station. Contacts B2 and B5 disconnect the intercom circuit. B4 applies an earth which stops the pulsing action of relay FL and keeps the relay operated. FL1 applies an earth to the exchange line supervisory lamps which glow steadily, indicating that the non-multiple extension is ready to accept the exchange call. When the multiple station clears, the exchange line is extended to the end of the multiple where Relay-unit Q 410 and the non-multiple extension are always connected. Exchange line current operates relay S. S1 completes a holding circuit for relay B.

When the EXCH button is released, relay D restores; D1 releases relay EX. EX1 and EX2 connect the extension to the exchange line and release relay A.

**28. Transfer from non-multiple extension to a multiple station [Dgms. Q(L) 410, 420 and 434].**—The exchange call is held as described in par. 24 while arrangements are made with, or via, the main station for the call to be taken over. The accepting station enters the exchange lines as described in par. 15. Although the interruption of the exchange line releases relay S, the following relays remain operated: A, EX, FL (pulsing), IL and RC. The prevention of a false call to the main station after the transfer of the exchange call is described in par. 10. Restoration of the handset at the non-multiple extension releases relay A and in turn all other relays, except EX, are released.

#### ADDITIONAL FACILITIES

**29. Operator recall [Dgms. Q(L) 412, 413 and 422].**—When a H.E.S. No. 3 is a subsidiary installation

connected to a P.B.X. a recall earth signal can be given to the P.B.X. from any station. Multiple stations are modified as shown in Dgms. Q(L) 412 and 413. KCI contacts apply an earth to the B wire of the line connected to the telephone; KC springs are operated by over-pressing the EXCH button. Due to a mechanical latching arrangement, the EXCH button must first be pressed until the plungers latch. Pressure on the button is then released but the plungers remain latched while the additional latch which operates the KC contacts engages. A second application of pressure on the EXCH button operates the KC contacts.

It should be noted that when the operator recall facility is required at an H.E.S. installation which also has S.T.D. private metering, then the recall signalling earth path must include a Filter, Frequency, No. 144A. The high impedance of the filter prevents the recall earth signal from shunting the meter.

At the non-multiple extension a recall signal is given by a second operation of the EXCH button but this earth signal calls the H.E.S. main (see par. 24) and the operator there must be asked to recall the P.B.X. operator.

**30. Exchange service restricted [Dgms. Q(L) 408 and 422].**—A Relay-unit Q 408 is added to the multiple station which is to have restricted service. At the controlling station, usually the main station, the telephone is modified by connecting the KB2 contact to the NS/BAR multiple wire (see Dgm. Q(L) 422 Notes 2 and 3). At the restricted station contacts BR1 and BR3 normally connect together the 'exchange line in' and 'exchange line out' terminals, by-passing the speech circuit of the telephone. BR4 short-circuits the bell. Access to the exchange line is thus prevented while relay BR is normal and incoming exchange calls are not signalled.

When it is desired to allow the use of the exchange line by the restricted station, the BAR button is pressed at the controlling station. Earth at KB2 is extended, via the NS/BAR wire in the multiple, to terminal T13 at the restricted telephone, relay BR coil and then to battery at terminal T18; relay BR operates. BR1 and BR3 connect the 'exchange line in' terminals to the telephone speech circuit via KX1, KX2 and KH1 (see par. 15). BR2 prepares a locking circuit for relay BR. BR4 removes the short-circuit from the bell. Operation of the EXCH button at the restricted station applies an earth to terminal 35, via KX3 operated to hold relay BR. Operation of the KX contacts also cause the exchange line supervisory line lamps to glow, indicating to the controlling station that the restricted station has seized the exchange line; the BAR button can now be released. An alternative holding circuit for relay

BR is provided via terminal 20, KX3 normal and KH2 operated. This allows the restricted station to hold an exchange call, if desired, without losing access to the line.

When the restricted station clears from the exchange line, restoring KX and KH contacts, the holding circuit of relay BR is broken. Relay BR restores and can only be reoperated by the controlling station.

The diodes CV 448 prevent the earth from the controlling station being applied to the C and D wires. The BAR button at the controlling station can be manually locked to give permanent access to the exchange line. The restricted station is freed under night service conditions unless special arrangements are made at the controlling station, e.g. the use of a separate key to control one of these facilities.

**31. Exchange line monitoring [Dgms. Q(L) 409 and 422].**—A monitoring facility can be provided at one station in a H.E.S. No. 3. A Relay-unit Q 409 is fitted in the instrument at the station which is to have this facility, the BELL/OFF button is changed for one labelled MON and KB2 springs are connected to telephone terminal 25.

When the MON button is pressed KB contacts are operated. Earth at KB2 operates relay M. Contacts M1 and M2 disconnect the telephone speech circuit from the intercom circuit and connect it to the extended exchange line. The monitoring station is now in parallel with the station using the exchange line normally. There is a reduction in transmission performance and for this reason the use of the monitoring facility is restricted.

**32. Exchange service during power failure [Dgms. Q(L) 405, 410 and 422].**—A power failure, either in the mains supply to the power unit or in the d.c. supply to the installation, does not interfere with normal exchange line service at any station although all other facilities cease.

Multiple stations can seize the exchange line as described in par. 15 and receive incoming calls as described in par. 20.

If a non-multiple extension is fitted, relay EX in Relay-unit Q 410, normally operated, releases when the d.c. supply ceases. EX1 and EX2 connect the non-multiple instrument across the exchange line. It will be noted that under these circuit conditions the a.c. bell circuit of the multiple stations is connected in parallel with the bell at the non-multiple extension and with the intercom multiple circuit. Under some circumstances this non-standard line termination may give trouble with exchange ringing; for this reason the 'power fail' emergency circuit arrangements must not be used as a substitute for standard night service arrangements at the non-multiple extension.

Reference :—Q 1011  
(S1/3)

END