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TELEPHONY: AUTOMATIC EXCHANGE PRINCIPLESCONTENTS

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INTRODUCTIONGENERAL

1. By definition, an automatic exchange system is one in which the calling subscriber can make, and complete, a telephone call to another subscriber, entirely by means of automatic switching devices and without the aid of an operator. Table 1 illustrates the general principles and shows how the automatic exchange performs the job of the manual operator.

Table 1 - Comparison of manual and auto operation

Subscriber	Manual exchange	Auto-exchange
1. Lifts handset to make a call-	Operator connects to caller and requests 'Number Please'	Line finder switching automatically locates calling line and transmits dial tone when exchange is ready to receive call
2. Manual: Subscriber tells operator the number required	Operator tests for engaged and if free connects and rings the required number, informs the called subscriber of incoming call and connects the two subscribers	Dial impulses operate switching devices in the exchange which find the required line, test for engaged and, if free, ring the called subscriber and disconnect ringing when subscriber answers
Auto: Subscriber dials the required number		

Table 1 - (cont)

Subscriber	Manual exchange	Auto-exchange
3. Call finished, subscribers replace handsets	Operator notes supervisory indication, challenges and then disconnects the subscribers lines	When caller replaces handset disconnection is automatic and practically instantaneous
4. If number is engaged	Operator must answer caller, check the required number and inform the caller that the number is engaged	The line is checked automatically and a special 'Number engaged' tone is returned to the caller

2. It is apparent, from Table 1, that the automatic exchange offers a number of advantages and disadvantages over the manual exchange. These are:

a. Advantages:

- (1) Phonetic errors in verbal instructions are eliminated.
- (2) Much faster setting up and clearing of calls.
- (3) Uniform, full time service by day or night.
- (4) Calls less liable to monitoring.
- (5) Staffing problems reduced.
- (6) Language difficulties resolved in multi-lingual areas.

b. Disadvantages:

- (1) Higher initial cost of equipment.
- (2) Higher standard of maintenance required.
- (3) Loss of personal attention of operator. (Overcome in most instances by the familiar, 'Dial 0 for operator').

3. The advantages of automatic telephone service are of even greater significance in the field where the increased speed of setting up and clearing calls permits a much more efficient use of the limited number of circuits available between formations. The high noise levels in field conditions also contribute to phonetic errors when setting up a manual call, these errors are eliminated in auto calling. The peak traffic requirements for military purpose can occur at any time of day or night and are obviously best catered for by an automatic system which is virtually independent of the number of operating personnel on duty at any time.

4. The system described in this regulation is known as the STROWGER or step-by-step system; it is the system used by the GPO and the one which has been adopted by the Army for military use. It is a CB system operating from a central battery located at the exchange; this is usually a 48V battery with its positive pole connected to earth. The requirements of the system are as follows:

- a. Subscriber (subs) must be able to signal the required number from his own equipment and know when the exchange is ready to receive his signals.
- b. Equipment at the exchange must respond to these signals by actuating switches which select both the calling and the called subscriber and connect them together.
- c. Ringing current must be transmitted to the called subscriber to activate his bell whilst ring tone is transmitted to the caller to indicate that the number is being rung.
- d. When the called subscriber answers, the ringing current must be disconnected and the speech circuit established.
- e. Should the called subscriber be engaged or unobtainable a recognized signal must be given to the caller.
- f. When the call is finished, both subscriber lines and equipment must be disconnected and the switches used to connect them released.

5. These requirements are met by the use of dial telephones at the subscribers end and relays and multi-contact rotary switches, known as selectors, in the exchange.

6. A signalling device is also required at the exchange to provide the following tones:

	<u>Field</u>	<u>Civil</u>	
	Hz	Hz	
a. Dial tone	- 400/25	33	- Continuous
b. Ring tone	- 400/25	133	- Continuous
c. Intermittent ring	- 25	133	- .4 on, .2 off, .4 on, 2.0 off
d. Line busy	- 400	400	- .75 seconds, .75 seconds off
e. Equipment busy	- 400	400	- .25 seconds, .25 seconds off
f. Number unobtainable	- 400	400	- Continuous
g. Intrusion tone	- 400		- 1 second on, 2 seconds off
h. Interrupted earth	-		- .75 seconds on, .75 seconds off
j. Flicker earth			.25 seconds on, .25 seconds off

SUBSCRIBERS EQUIPMENT

7. The switching in an automatic system must be controlled by the subscriber. This is done by means of a dial mechanism, the contacts of which are so arranged that they open and close the subscribers d.c. line loop to the exchange, and by doing so complete a battery cct and activate relays in the exchange.

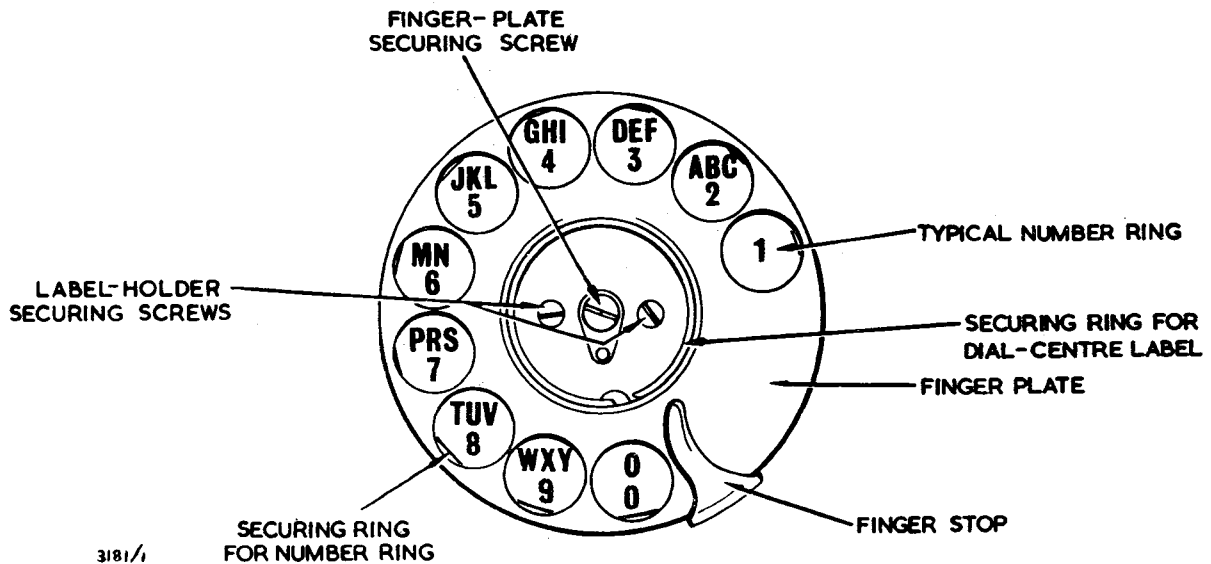


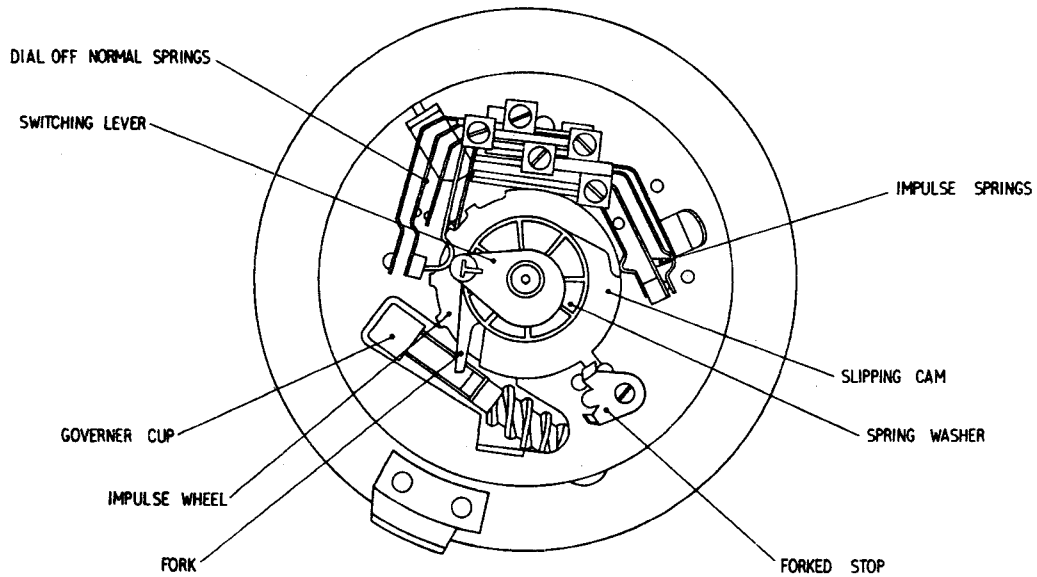
Fig 1 - Front view of telephone dial

The dial

8. The dial carries a rotatable finger plate (Fig 1) which has 10 finger holes numbered 0-9. To dial a number, the dial is rotated in a clockwise direction, using the appropriate finger hole until movement is arrested by the finger stop. The dial is then released to return to normal under the action of its own internal spring and a governor which controls the speed of return. Mounted on the back of the dial (Fig 2) are two groups of contact springs:

- a. The impulse springs.
- b. The Dial OFF - NORMAL springs, (usually abbreviated to DON springs).

9. When the dial is at rest, the impulse springs are made and the DON springs are open. As soon as the dial is moved from normal the DON springs make and the impulse springs remain made until the dial begins its return movement under the action of an internal coiled spring.



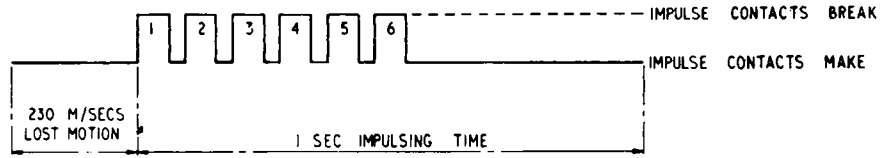
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Fig 2 - Rear view of telephone dial

10. On the free, return motion of the dial, no action takes place for the first 230 milliseconds (LOST MOTION TIME). After this time lapse the impulse springs will open and close in accordance with the number dialled, eg, if No 6 is dialled, the impulse springs will open and close six times after the nominal 230 milliseconds (ms) delay. The zero is effectively ten and when 0 is dialled, 10 impulses are sent to line. The DON springs remain closed all the time the dial is off normal.

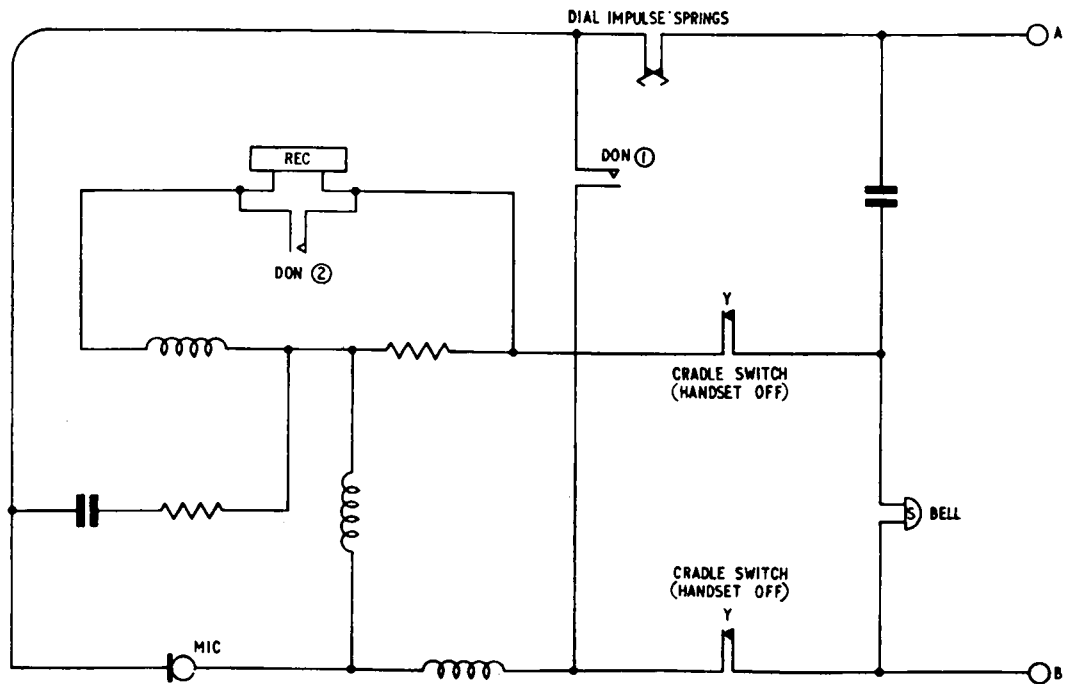
11. The governor ensures that the speed of dial return is constant. The impulse wheel which activates the impulse springs is designed to give a break period of $66.2/3\%$ and a make period of $33.1/3\%$. The standard impulsing frequency is 10 impulses per second, ± 1 impulse per second, therefore each impulse has a duration of 100 milliseconds, comprising 66.7 milliseconds break period and 33.3 milliseconds make. The sequence of makes and breaks is known as the impulse train.

12. The 230 milliseconds lost motion time, together with the time taken by the subscriber to dial a second number, allows time for the circuits in the exchange to prepare themselves for the next action. Fig 3 illustrates the impulse train when No 6 is dialled.



3181/3

Fig 3 - Dial impulse train



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Fig 4 - Dial telephone, simplified schematic

Dialling and the auto-telephone
(Fig 4)

13. The auto-telephone is a perfectly normal CB telephone with the addition of a dial to provide signalling facilities to the auto-exchange. The impulse springs and DON spring sets 1 and 2 are integral parts of the dial mechanism as explained in para 6. When the dial is in use, ie, off normal, both sets of DON contacts are closed. DON (2) contacts short circuit the receiver to eliminate impulsing clicks. DON (1) contacts complete a d.c. loop from A to B via the impulse springs, DON contacts, cradle switch (handset off).

14. When making a call, the subscriber first lifts the handset off its cradle. This actuates the cradle switch and completes a d.c. loop across lines A and B via the microphone circuit and impulse springs.

15. This d.c. loop is used to operate the subscribers line relay at the exchange. The line relay activates other relays and switches in the exchange and causes dial tone to be returned to the caller, indicating that he can now start to dial the number required.

16. The action of dialling causes the impulse springs to make and break the d.c. loop to the exchange where another relay operates in unison with the impulses transmitted and steps a rotary switch to the required position.

17. When the call is finished, replacing the handset on its cradle causes the cradle switch to break the d.c. loop to the exchange, the relays are released and all circuits revert to normal.

EXCHANGE EQUIPMENTThe uniselector
(Fig 5, 6, 7, 8)

18. The uniselector is basically a rotary switch which is operated electrically by the impulses transmitted from the subscribers telephone. The type of uniselector commonly used in military field exchanges is the BPO type No 2, illustrated in Fig 5 and 6. As will be seen from the drawings, there are a number of contacts arranged in semi-circular rows of 25. The number of rows will depend upon requirements and can vary from 2 to 10. The whole assembly of fixed contacts is known as a BANK, an individual row of 25 contacts is known as an ARC.

19. Associated with each arc is a wiper assembly which can be rotated to switch to any selected contact on the arc. These wipers can be single ended or double ended, bridging or non-bridging. When used double ended, each arc contact is swept over twice for each revolution of the wiper assembly.

20. When used single-ended, the wipers are arranged alternately at an angle of 180° to each other so that only alternate wipers are in contact with the bank at any given time. Thus by commoning adjacent pairs of wipers it is possible to sweep 50 contacts for each revolution. Wiper No 1 sweeping contacts 1 to 25 (arc No 1) for the first 180° degrees of rotation, Wiper 2 sweeping contacts 26 to 50 (arc No 2) for the second 180° degrees. Connections to the wipers are made by the brushes and

collector rings shown in Fig 7. Each wiper has its own brush and collector.

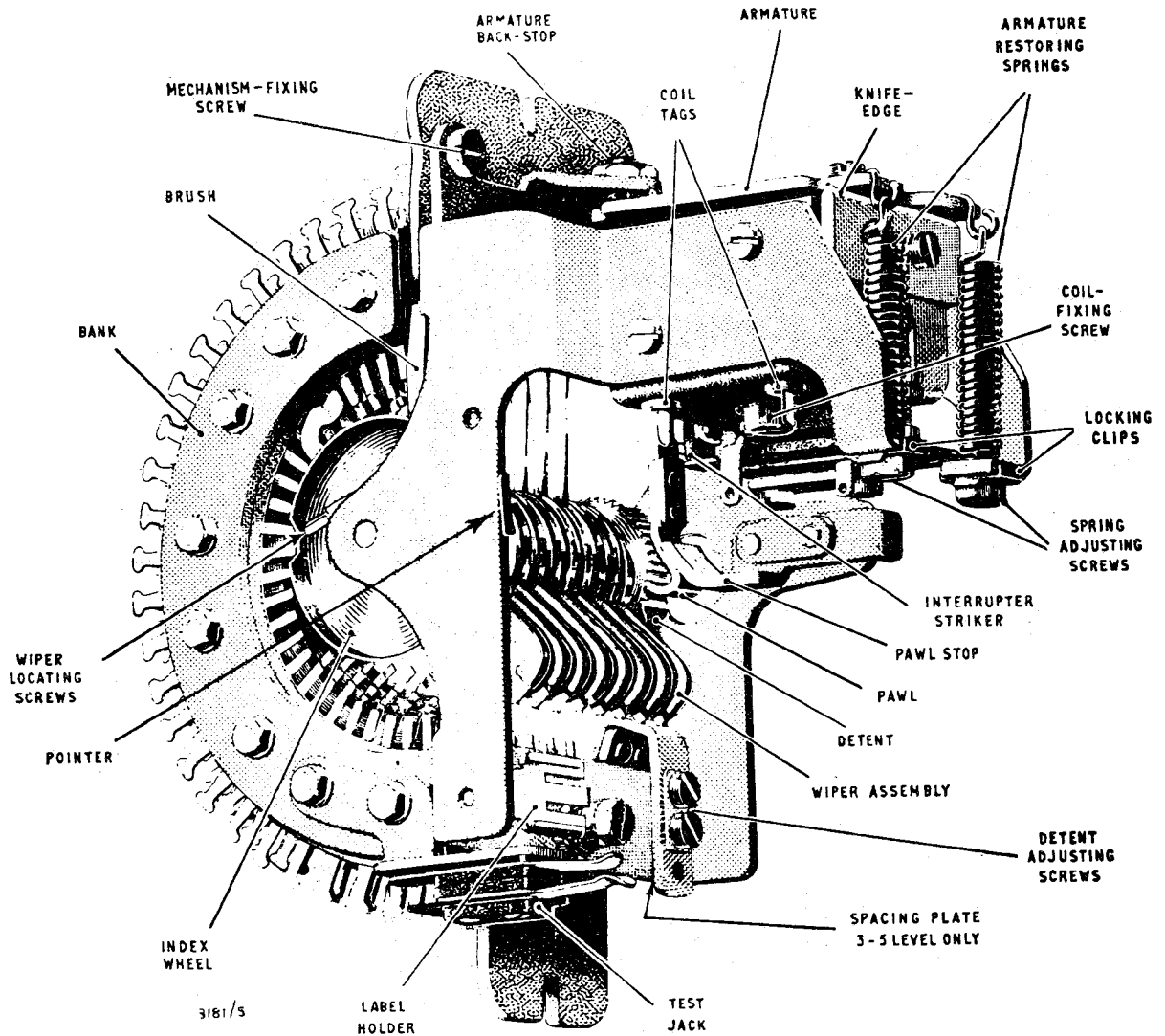


Fig 5 - Uniselector BPO No 2, left side

21. For some circuits it is necessary for the wipers to maintain continuous contact with the bank, ie, the wipers make before break and are known as bridging wipers. Other requirements call for break before make and these wipers are non-bridging. The two types of wipers can be assembled in any desired combination to meet circuit requirements.

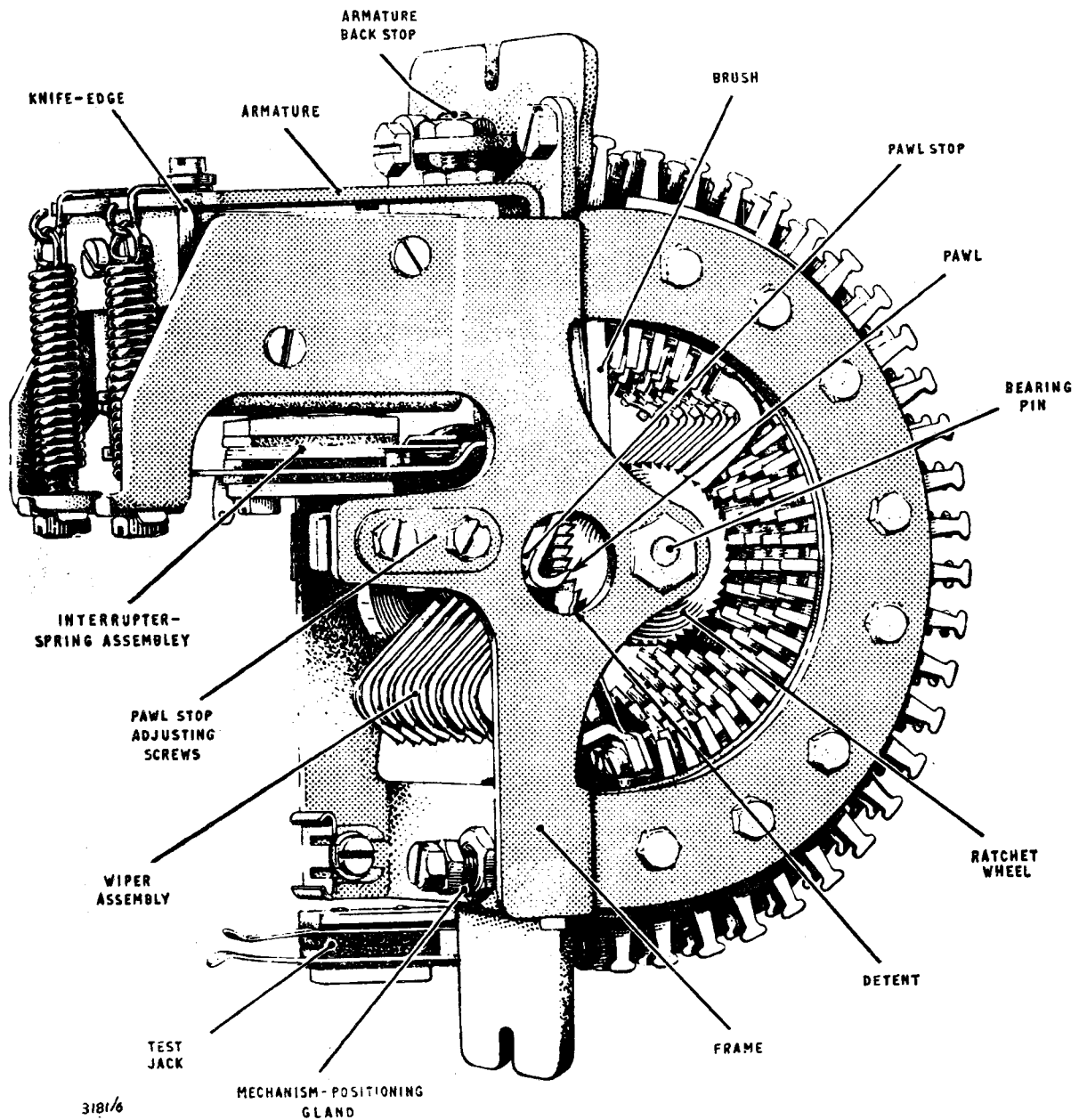


Fig 6 - Uniselecter BPO No 2, right side

22. The wipers are assembled on, but insulated from, a rotatable steel shaft which also carries the ratchet wheel and the index wheel. The index wheel indicates the position of the wipers in the bank. The ratchet wheel is used to rotate the wipers.

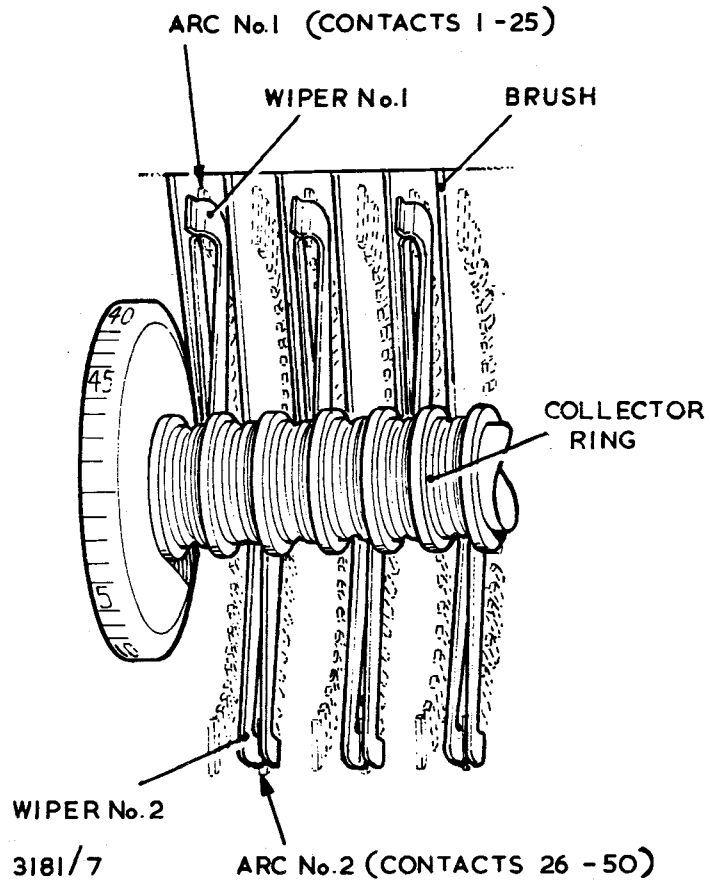


Fig 7 - Uniselector wiper and brush arrangement

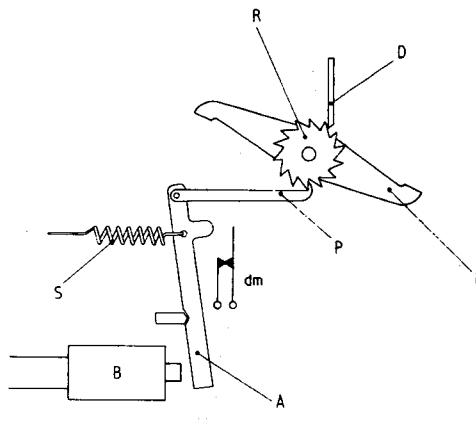
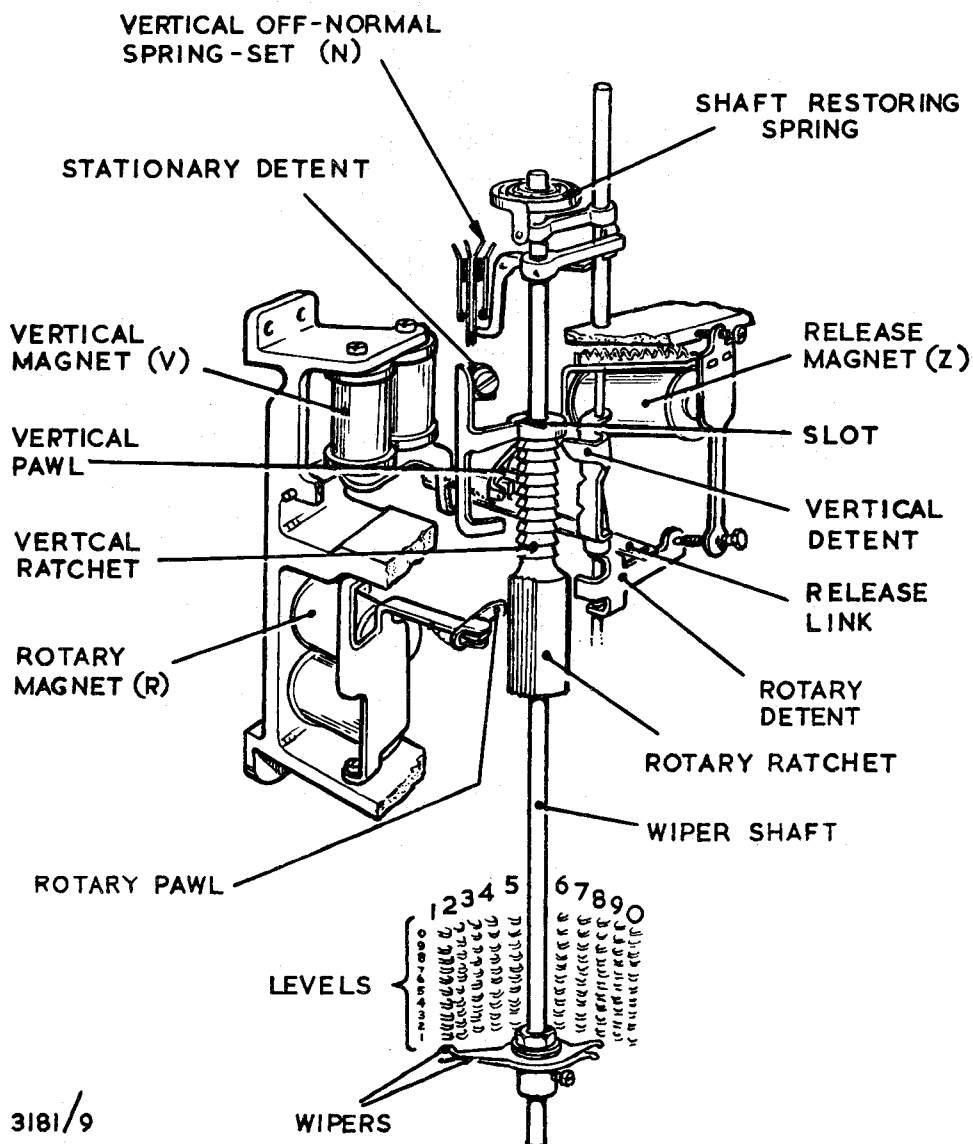


Fig 8 - Uniselector rotating mechanism

23. The electro-mechanical arrangement for rotating the wipers is shown in Fig 8. When armature A is attracted to the electro magnet B, it actuates pawl P which moves forward (right in Fig 8) and engages in the next tooth of the ratchet wheel. The ratchet wheel is prevented from moving backwards by detent spring D. When the electro magnet is de-energised the armature releases and is restored to normal by spring S. Pawl P moves with the armature and turns the ratchet wheel by one tooth. The wipers F are on the same shaft as the ratchet wheel and turn with it. Contacts dm are opened when the armature is operated; these contacts form part of the complete drive circuit for the unselector which will be explained later.

24. It is important to note that with the mechanism described the wipers only move when the potential operating the electro magnet is removed and NOT when it is first applied. It is known as the Release or Reverse drive mechanism.



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Fig 9 - Pre-2000 type selector mechanism

Two motion selector (100 line) pre-2000
(Fig 9)

25. This selector is commonly used in large static exchanges and as the name implies it is capable of two motions, a vertical motion and a rotating motion.

26. The bank of contacts are arranged as shown, in groups of 10 arranged one above the other in 10 levels to give 100 contacts or outlets in the shape of a hollow half cylinder. It is usual to refer to the contacts of a selector as outlets.

27. The outlets are numbered as shown. The numbering will be explained later in the text.

Level 0	01	02	03	04	05	06	07	08	09	00
Level 9	91	92	93	94	95	96	97	98	99	90
Level 8	81	82	83	84	85	86	87	88	89	80
Level 7	71	72	73	74	75	76	77	78	79	70
Level 6	61	62	63	64	65	66	67	68	69	60
Level 5	51	52	53	54	55	56	57	58	59	50
Level 4	41	42	43	44	45	46	47	48	49	40
Level 3	31	32	33	34	35	36	37	38	39	30
Level 2	21	22	23	24	25	26	27	28	29	20
Level 1	11	12	13	14	15	16	17	18	19	10

28. The wipers are carried on the vertical shaft and can be raised and rotated, by the electro magnets, to make contact with any desired outlet.

29. The vertical magnet V is made to operate in response to the first impulse train and raises the wipers to a level corresponding with the number dialled.

30. The second impulse train is now diverted to operate the rotary magnet, this again steps in sympathy with the impulses received and moves the wipers along the level to the desired number.

31. Thus if No 57 is dialled, the first digit, 5, will cause the vertical magnet to operate and release 5 times and so step the wipers up to level No 5. When No 7 is dialled the impulse train is made to operate the rotary magnet R, seven times, therefore the wipers are moved around to the 7th contact on level 5, ie, No 57. The shaft is held in position by the action of the vertical and rotary detents shown in the drawing.

32. When the call is finished it is necessary to cause the wipers to retrace the route taken when setting up the circuit. This is done by energising the release magnet which releases the vertical and rotary detents. The weight of the shaft and wipers is now carried by the stationary detent. The shaft restoring spring, wound up during the setting up of the circuit, now unwinds and rotates the shaft until a vertical slot, cut through the vertical ratchet, coincides with the stationary detent and the shaft drops down to its normal position.

Numbering

33. The selector caters for 100 outlets and it is necessary to operate both the vertical magnet and the rotary magnet to select a given number. It is therefore necessary that the 100 lines selected must each bear a double number; we cannot have single numbers 1 to 9 nor can we have the 3 digit number of 100. Remember also that dialling the digit 0 produces 10 impulses, consequently the top level of the selector must be level 0 and the tenth outlet of all levels must also be selected by the 0 digit. The system of numbering is therefore from 00, 01 etc to 99 as shown on the chart.

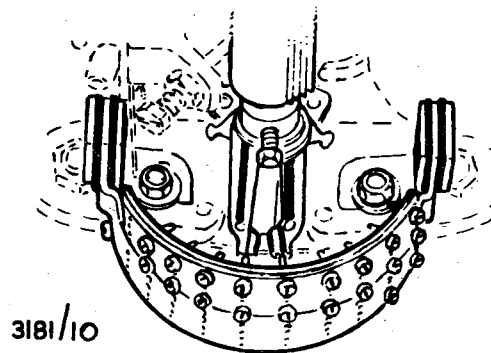


Fig 10 - Auxiliary screw arc

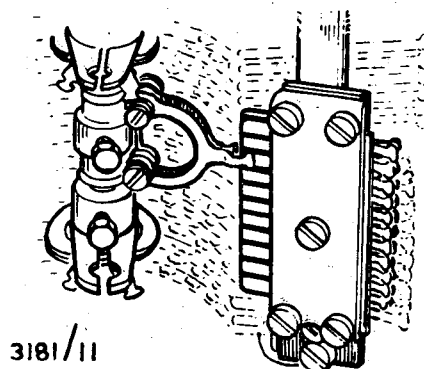


Fig 11 - Vertical marking bank

Mechanical spring sets and other special features

34. The mechanical motion of the shaft of the two motion selectors is used to operate various contact springs sets and so provide necessary switching associated with the movements of the wipers. The following list gives the spring sets most commonly used, the letters in brackets indicate the coding generally used in circuit diagrams.

- a. Vertical Off - Normal Spring Set (N) - This set is shown in Fig 9. It operates immediately the wipers are moved from their normal position by the first vertical motion of the shaft.
- b. Rotary Off - Normal Spring Set (NR) - Operates immediately the wipers commence their rotary motion and releases when they leave the bank.
- c. Vertical Spring Set (V) - (Used also for Vertical Magnet). Operated by the armature of the vertical magnet.
- d. Rotary Spring Set (R) - (Used also for Rotary Magnet). Operated by the armature of the rotary magnet.
- e. Level Springs (NP) - Sometimes referred to as NORMAL POST SPRINGS. Operated when the wipers are raised to any particular level or levels and are unaffected by the rotary motion of the wipers.
- f. 11th Spring Set (S) - Sometimes referred to as CAM SPRINGS. Operates when the wipers move to the 11th rotary position and releases when they leave that position.
- g. Release Spring Set (Z) - Operated by the armature of the release magnet when the magnet is energised.
- h. Auxiliary Screw Arc (Fig 10) - Generally used as a PBX arc, ie, to provide automatic hunting over consecutive lines such as those associated with a manual switchboard. It consists of a metal arc with 100 tapped holes corresponding to the 100 sets of bank contacts. Special screws are inserted into the holes where it is required to provide earthed bank contacts, ie all except the last line of a PBX group. These contacts have their own special wiper.
- j. Vertical Marking Bank (Fig 11) - The vertical marking bank consists of 11 pairs of contacts, one pair for the normal rest position and a pair for each level, arranged so that the vertical marking wipers are connected to the appropriate pair of contacts as shown. The wipers are not affected by the rotary action of the selector.

Note: The two motion selector is NOT used in Field exchanges as it is not mechanically suitable for use in a mobile role.

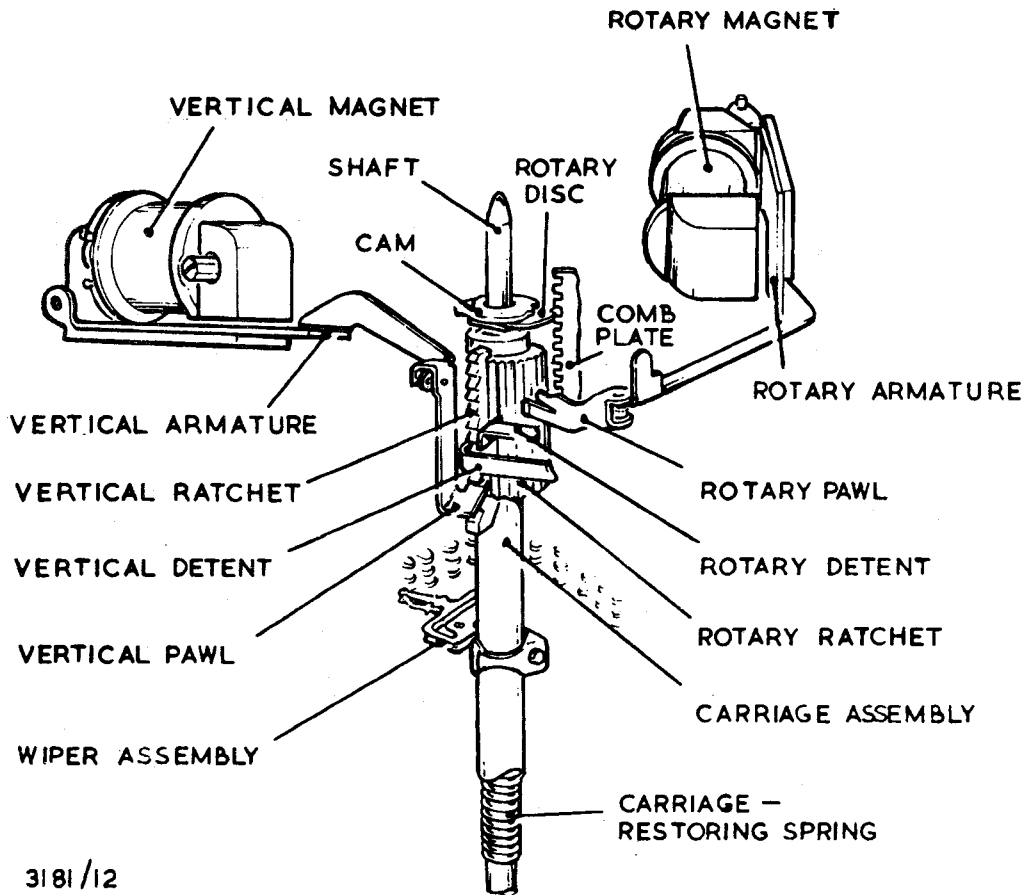


Fig 12 - 2000 type selector mechanism

The 2000 type selector
(Fig 12)

35. This is the present BPO standard type of 2 motion selector and is an improved version of the type already described. Fig 12 illustrates the mechanism.

36. There is no release magnet on this type of selector and it is considerably smaller and faster in operation than the pre-2000 type (Speed is approx 40 steps per second). The vertical and rotary stepping actions are controlled by two ratchet and pawl systems as shown. The wipers and ratchets are carried on a hollow carriage which slides on a fixed shaft and consequently is much lighter and easier to operate than the previous type. The helical restoring spring is mounted inside the hollow shaft. The action of the vertical magnet raises the wipers to the required level and extends the restoring spring. When the shaft is rotated the vertical ratchet moves with the shaft and disengages from the vertical pawl and detent. The shaft is retained in the level by the entry of the eccentric rotary disc into the comb plate as shown. The restoring spring is wound up during rotary action. The wipers are released by driving them on to the 12th position of the

level where the notch in the disc comes into line with the comb plate and the disc and wiper carriage are free to fall, under the tension of the restoring spring. At the end of the fall, the rotary detent is disengaged from the ratchet and the carriage rotates back to normal under the uncoiling action of the restoring spring. Unlike the unselector which has a reverse drive mechanism, the 2 motion selector has forward drive mechanism, ie, the wipers are moved when the appropriate magnet is energised and the armature moves the pawl which actuates the ratchet.

Relays, types 600 and 3000, coding

37. In addition to the dial and selectors described, numerous relays are employed to perform various circuit functions in the exchange. The two most commonly used are the types '3000' and '600'.
38. The type 3000 is a general, all purpose type of relay and can carry two spring sets with a maximum of nine springs per set. Speed of operation or release can be varied in the usual ways, ie, by use of slugs, sleeves, armature designs etc.
39. The type 600 is a smaller and cheaper version of the 3000 type and the maximum number of springs it can carry is two sets of 6. It is normally used for the subscribers line and cut off relay.
40. To facilitate recognition of the function of a relay in circuits and diagrams a letter code has been adopted. The most commonly used letters are as follows:
- A - Impulse accepting relay - accepts impulses from line.
 - B - Hold and guard relay - prevents apparatus already taken into use being seized for another call.
 - C - Impulse control relay - sets up circuit for impulse path and determines the end of each train of impulses.
 - D - Supervisory relay.
 - DM - Drive magnet.
 - dm - Drive magnet interrupter contacts.
 - E - Rotary impulse control relay.
 - F - Ringing trip relay.
 - G - Busy or test relay.
 - H - Wiper switch relay.
 - I - High impedance relay.
 - J - Booster relay - applies increased voltage where required.
 - K - Unselector switching relay.

- L - Line relay.
 N - Vertical off-normal springs.
 R - Rotary magnet.
 S - Cam spring.
 V - Vertical magnet.
 Z - Release magnet.

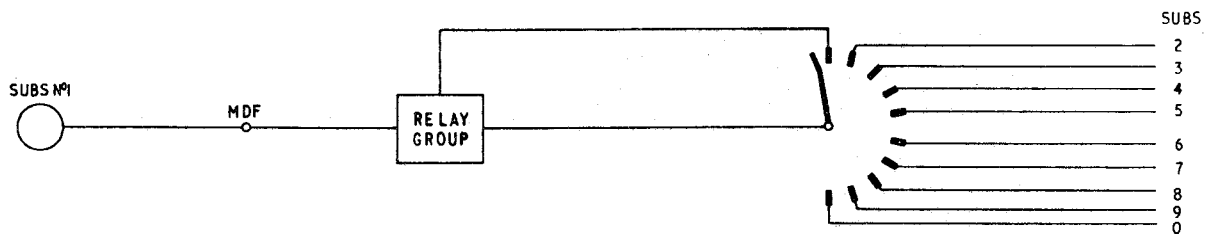


Fig 13 - Simple 10 line selection

PRINCIPLES OF THE STROWGER SYSTEM10 line selection

41. Figure 13 illustrates the simplest case of selection. As there are only ten subscribers, and only one stage of selection, the subscribers are number 0-9, ie, single digit dialling. Each subscriber has his own dial telephone connected via a distribution frame to its own relay group and particular contacts on the arc of the selector.

42. When sub No 1 makes a call, he first lifts his handset and so actuates his line relay as explained in para 7. The circuit of the uniselector stepping mechanism is prepared to accept dial impulses and, when the appropriate number is dialled, will step the wipers round the arc to the contacts of the required subscriber. This simple system would obviously only provide dialling facilities for sub No 1. To provide full facilities to all subscribers the system would have to be enlarged as shown in Fig 14.

43. It will be noted that the contacts on each arc are connected to the same contacts on the other arcs, thus allowing any subscriber to connect to any other subscriber in the group. The diagram is simplified: in practice two wires are provided for speech and signalling.

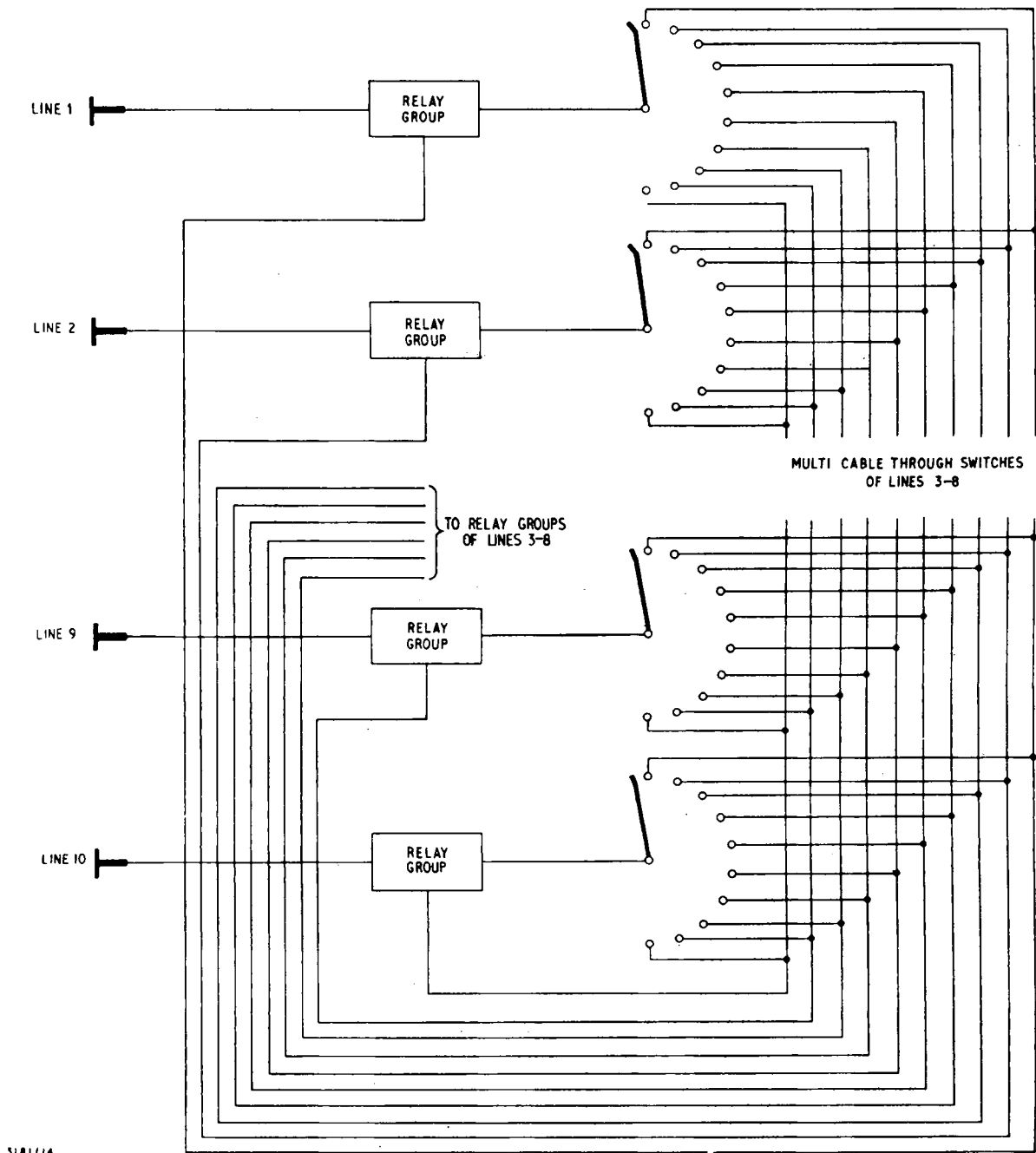
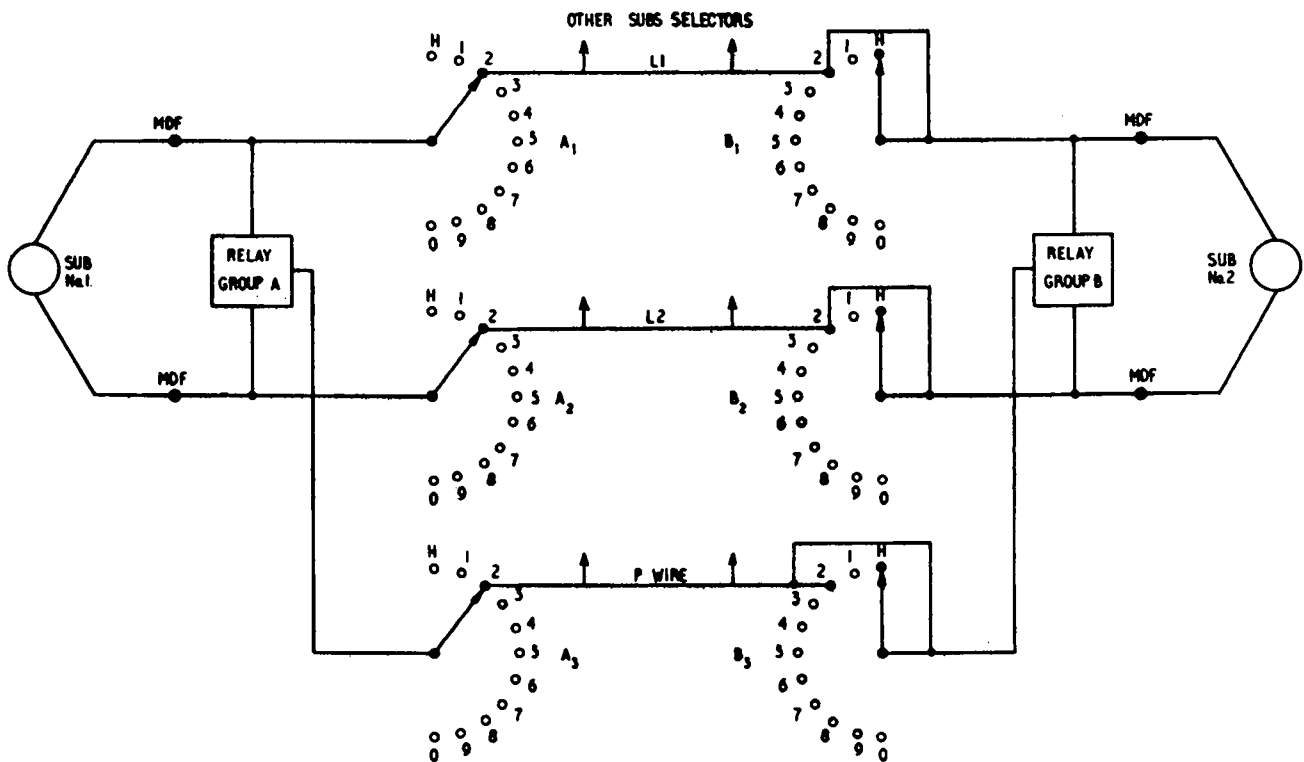


Fig 14 - 10 line selection with relay group

The relay group

44. This group must perform the following functions:

- a. Recognize the incoming call and transmit dial tone to caller.
- b. Actuate the selector magnet in accordance with the digit which is dialled.
- c. Test the called line.
- d. If line is free, apply ringing current.
- e. If line is not free, return engaged tone to the calling subscriber.
- f. Disconnect ringing current when called subscriber lifts his handset.
- g. Sagefuard the circuit against interruption while the call is established.



3184/15

Fig 15 - Connection between two subscribers

The P wire
(Fig 15)

45. The necessity to test the called subscribers line and to safeguard the established circuit calls for a 3rd connector throughout the exchange. This connector is known as the P wire. Fig 15 shows a simplified layout when No 1 subscriber is connected to No 2.

46. In the rest condition all six wipers are on the 'home' contacts, ie, no connections are made. When sub No 1 lifts his handset to make a call he completes a d.c. loop for the relay group and (if the circuits are available) will receive dial tone from the group to indicate that he can proceed to dial. When he dials (digit 2 in this case) the relay group will cause the A selector to operate twice thereby putting the three A wipers on to No 2 outlets of arcs A1, A2 and A3.

47. The circuit conditions of sub No 2 will be checked by testing the potential on the P wire. If this shows No 2 is engaged, the relay group will send engaged tone back to No 1. If No 2 is free, ringing current will be applied to his line until he lifts his handset to answer the call. While the call is established the P wire and relay groups will hold the circuit, prevent other selectors from connecting to No 2 outlet and return engaged tone to any other subscriber who endeavours to contact No 1 or No 2 subscriber.

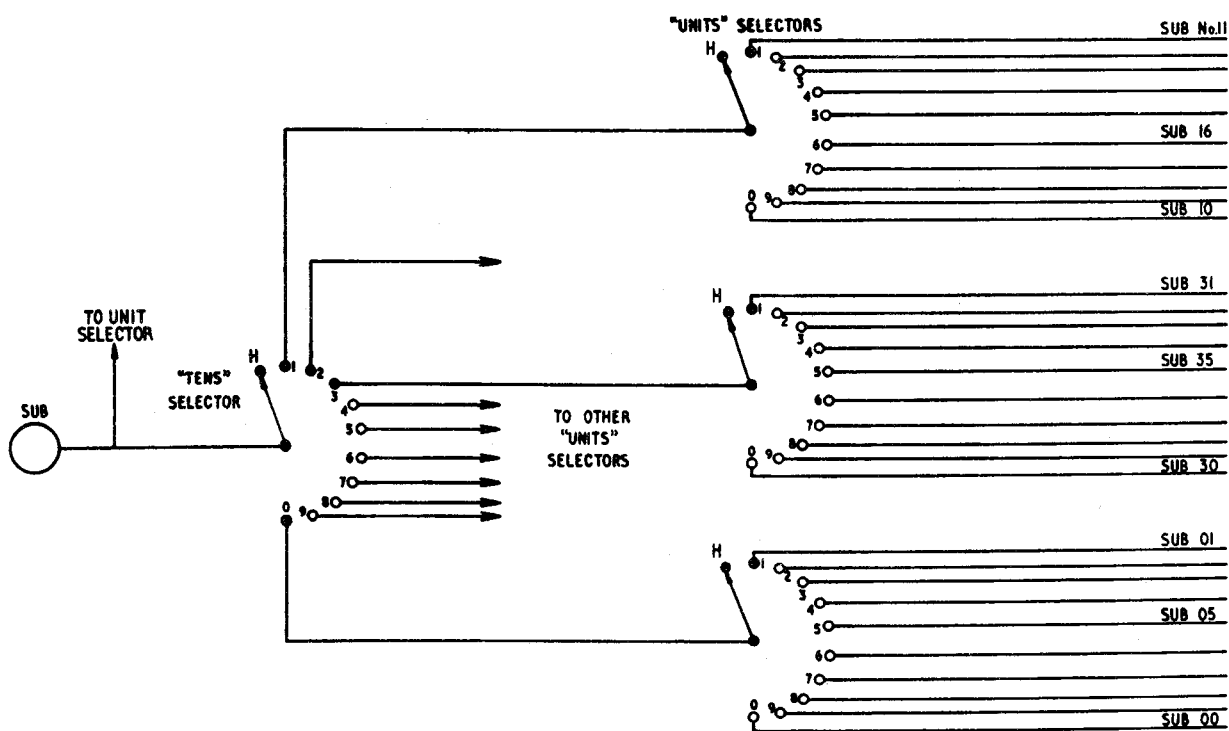
48. At the completion of the call, the handsets are replaced, the d.c. loop is broken, the relay groups restore the selectors to home position and the circuit is ready for the next call.

100 line selection
(Fig 16)

49. If there are more than 10 subscribers to be interconnected, it becomes necessary to elaborate on the simple circuit shown in Fig 13, and to resort to two digit dialling and two steps of selection as shown in Fig 16.

50. As already explained, whenever there are two stages of selection we cannot have single figure or treble figure dialling and so the hundred subscribers would in theory be numbered 00, 01, 02 to 99. The first selector responds to the first digit which is dialled, the wipers move round to the selected outlet and connect to the wipers of a second selector which responds to the second number dialled. Thus, if subscriber No 35 is called, the 'tens' selector will move to position 3. The 3rd 'units' selector, which carries the ten subscribers in the thirty group, will move to position 5 and so connect to No 35.

51. The two motion selector already described can be used to perform the above operation and so economise on the number of selectors required, ie, one two motion selector instead of 11 uniselectors. It should be remembered though, that the carriage of the 2 motion selector must be free to move vertically and this of course makes it unsuitable for use in a mobile role but the general principle described, with uniselectors, is used in field automatic exchanges.

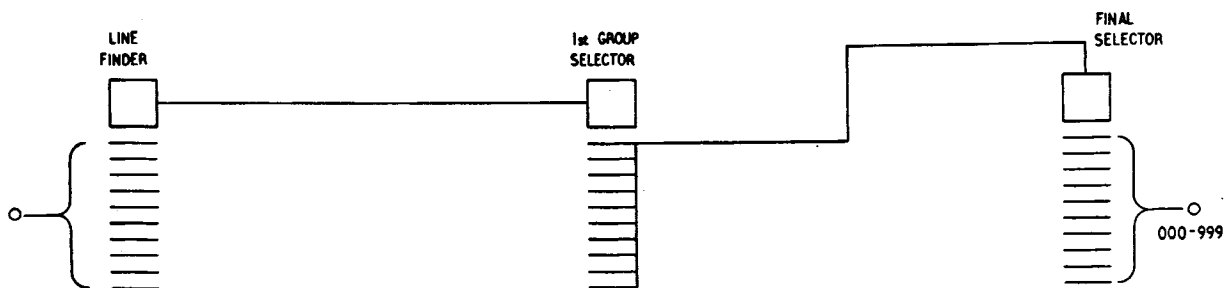


3181/16

Fig 16 - 100 line selection

1000 line selection

52. With the addition of a 3rd group of selectors, the 100 line exchange, illustrated in Fig 16, can be expanded to cater for 1000 lines. This necessitates three digit dialling and the subs Nos would theoretically run from 000, 001, etc to 999, the first selector responding to the 'hundreds' digit and connecting to the 'tens' digit selector and finally to the 'units' selector.



3181/46

Fig 17 - Trunking diagram, 1000 line exchange

Trunking
(Fig 17)

53. The lines connecting a group of selectors to the next group are known as trunks. Simplified diagrams to illustrate the route taken by calls through an exchange are known as trunking diagrams. In these diagrams, selectors and connectors which perform similar functions are shown once only. The trunking diagram for a 1000 line exchange is shown in Fig 17.

Practical systems

54. The system so far described, while workable, would not be practical nor economical because of the very large number of switches required. Take the case of a 100 line exchange, the maximum number of connecting circuits in operation at any one time could not exceed 50 and therefore there would be 50 selectors not in use. Traffic analysis has shown that the actual number of simultaneous calls likely to take place even during a busy period would probably not exceed 10 and therefore 90% of the selectors provided are superfluous. It therefore becomes necessary to have a system which will meet the practical requirements while using the least number of selectors.

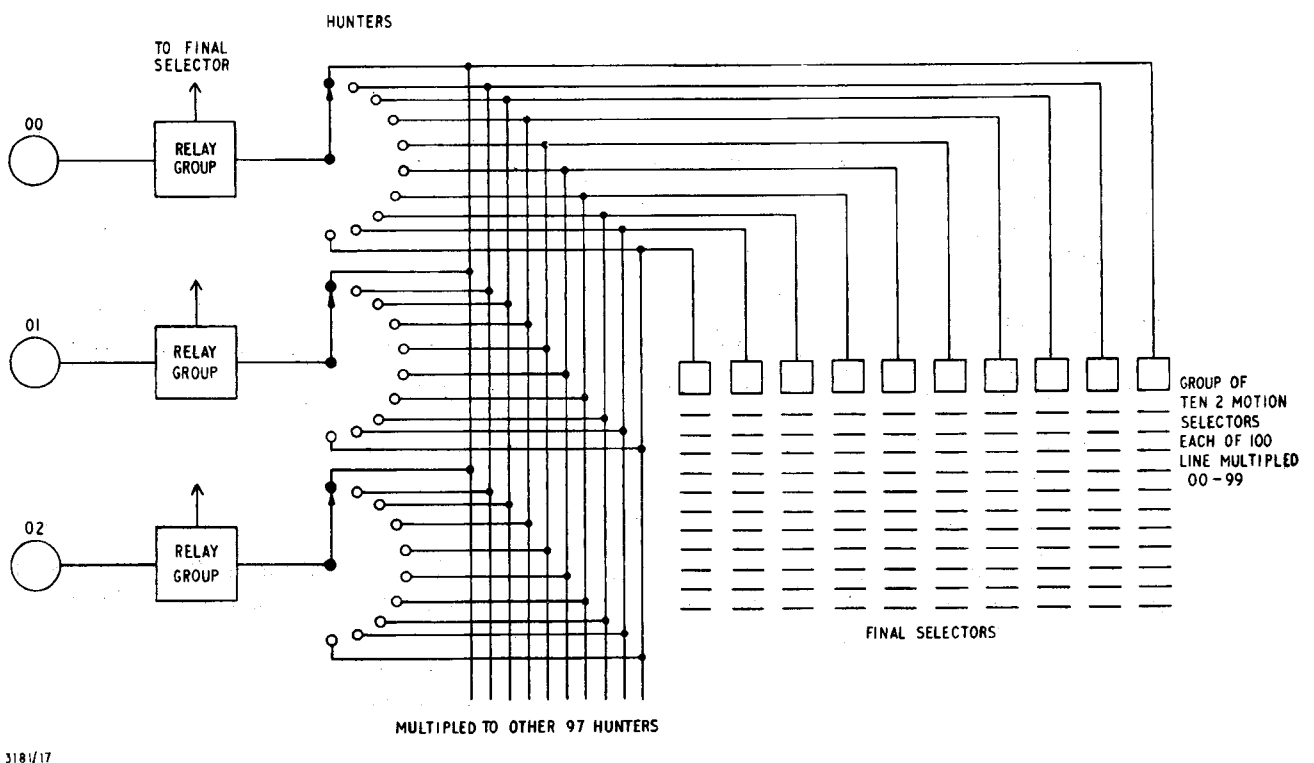
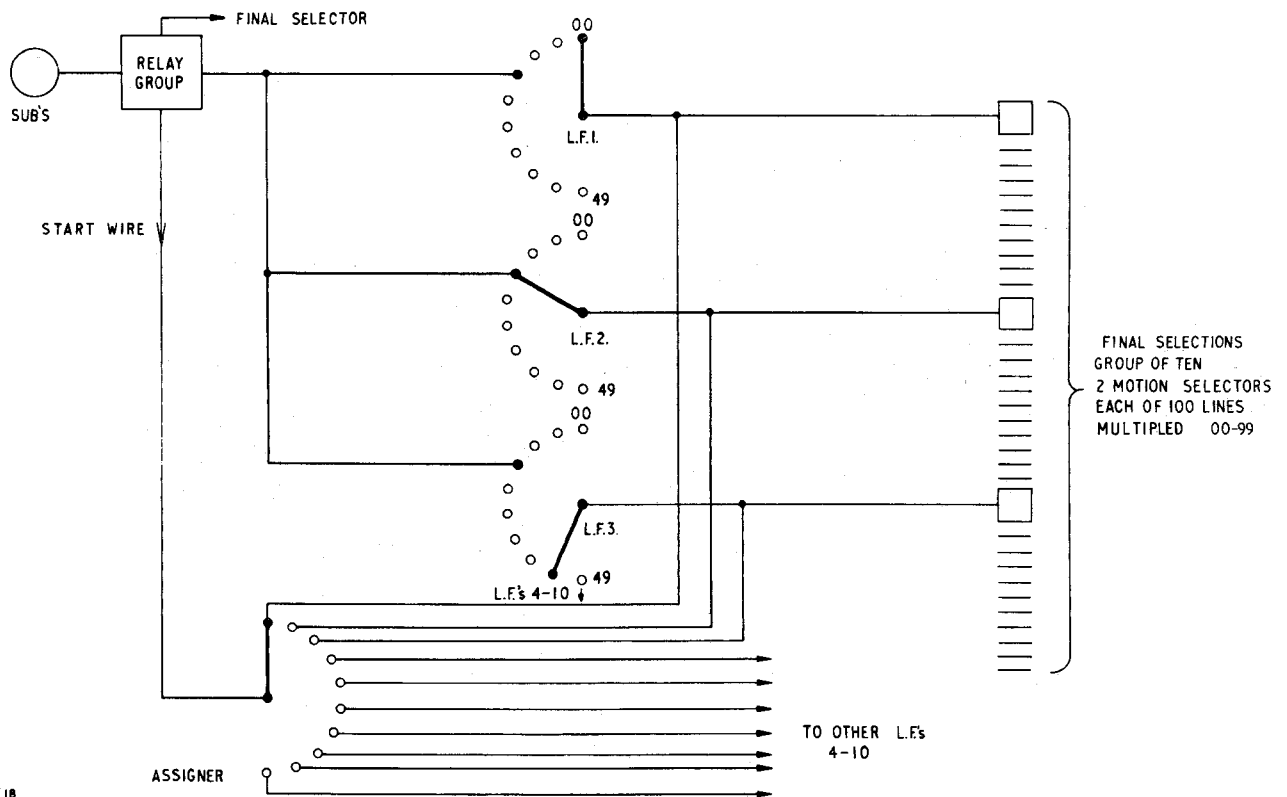


Fig 18 - Pre-selection by hunters



3181/18

Fig 19 - Pre-selection by line finders

Pre-selection (100 lines)
(Figs 18, 19)

55. Instead of giving each subscriber his own individual chain of selectors, provision is made to connect any subscriber to one of a group of ten selectors which will respond to dialling. There are two methods of doing this:

- a. By HUNTERS.
- b. By LINE FINDERS.

56. Both methods use a selector for pre-selection. When used as a HUNTER, each subscribers line is connected to the wipers of his own rotary switch and this switch hunts for a free selector in the group. When used as a linefinder the subs lines are connected to the arcs of a common switch which searches for the calling line; this system is more economical of equipment where traffic is relatively light.

Pre-selection by hunter

57. When the subscriber lifts his handset to make a call, the hunter is activated and automatically hunts until it finds a selector which is not in use. Dial tone is returned to the caller when a free selector is found. The final selectors then respond to the impulses sent from the dial and connect to the required number as already described.

Pre-selection by linefinders

58. In this case a 50 outlet uniselector (LINEFINDER) is associated with each two motion final selector. The subscribers line circuits are connected to the arc contacts of the linefinder, Fig 19. In the example shown, each subscriber would be connected to five linefinders, ie, he has a possibility of five outlets for his call, using any one of the five LFs.

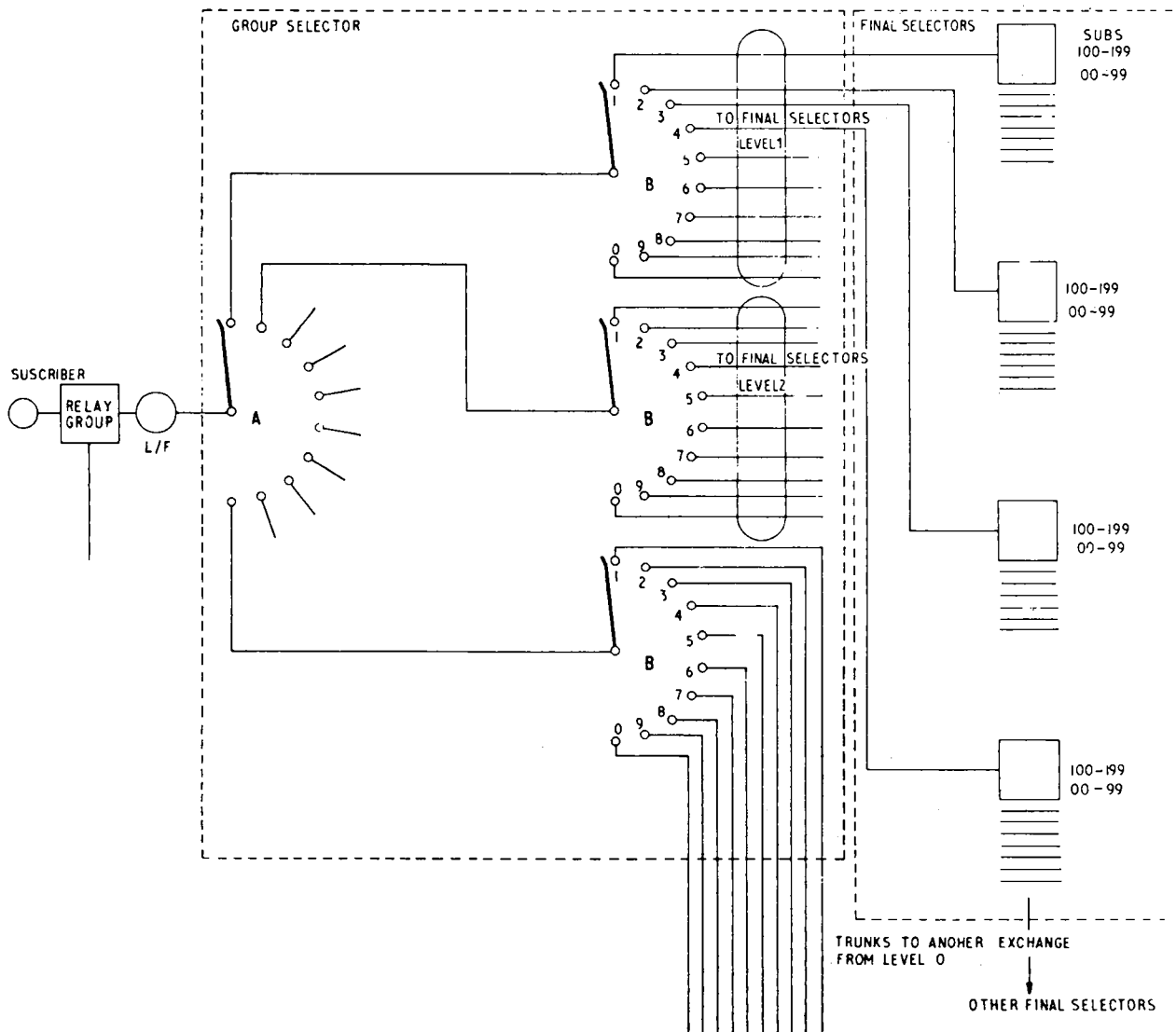
59. Another uniselector, known as the assigner, is used to select a free linefinder (and associated final selector) and to cause the linefinder to rotate and stop when the calling line is found. Every subscriber has access to one or more assigners which are operated by the subscribers relay group. The sequence of action is:

- a. Sub lifts handset to make a call.
- b. The d.c. loop provided operates the appropriate relays and starts the assigner through a start circuit (not shown).
- c. The assigner locates a free selector (if not already pre-selected) and then causes the associated linefinder to rotate and find the callers line.
- d. Dial tone is returned to the caller.
- e. Caller dials the required number, the final selector responds to the impulses and connects to the called subscriber.
- f. Assigner reverts to the rest condition ready for the next call; alternatively the assigner may be stepped to the next free linefinder ready for the next caller.

60. There are many variations of the above system but the basic object in each case is to reduce the amount of equipment required to meet the practical needs of the subscribers. Typical military field exchanges use 1 assigner, 8 linefinders, 8 group selectors, 8 final selectors for every 50 subscribers.

Group and final selectors
(Fig 20)

61. In the larger exchanges using three digit dialling the principle of selection is carried a stage further with the use of the group selector. This selector responds to the first digit and then commences to hunt automatically for a free final selector. The final selector responds to the last two figures dialled. Alternatively the automatic searching action of the group selector can be used to hunt for a free trunk to another exchange.



5181/19

Fig 20 - The group selector

62. For clarity, the group selector shown uses two uniselectors A and B. In large static exchanges a two motion selector would normally be used, in which case the vertical movement of the selector would correspond to the A arc shown in the diagram and the rotary movement through the levels would correspond to the B arcs.

63. A number of final selectors are allocated to each group of subscribers, Fig 20 shows four final selectors all connected to subscribers 100-199. Again, the final selectors can be of the two motion type or two separate uniselectors as used in the field.

64. The O level of the group selector is shown feeding the trunk circuits of another exchange and other levels of the A switch could be used to feed other groups of final selectors or could be fed off as junctions to other exchanges which would only require a single digit to connect. The action sequence is:

- a. Linefinder locates the calling subscriber and connects him to a free group selector.
- b. The A switch of the selector responds to the first impulse train and steps to the appropriate number.
- c. The subscriber is now connected via the wipers and arc contacts of the A switch to the wipers of the selected B switch, or to the selected level of the two motion selector.
- d. The B switch rotates automatically until it finds a free final selector and connects to it.
- e. The final selector now responds to the last two digits dialled and connects to the called subscriber.

65. The essential point to remember is that the group selector operates automatically after receipt of the first impulse train, it will then hunt for, and seize, the first free final selector. The calling lines are now extended to the final selector which responds to the last two digits dialled, ie, the action of the final selector is controlled by the impulse train and is not automatic.

66. The number of final selectors, group selectors and linefinders allocated to each group of subscribers will determine the maximum number of simultaneous calls within a given group and can be varied for different groups. Assuming we allocate 10 of each to every 100 subs, then in the case illustrated it is possible to have 10 simultaneous calls going on to subscribers in the 100-199 group. 10 calls to subs in the 200-299 group and so on up to a maximum of 100 calls on a 1000 line exchange.

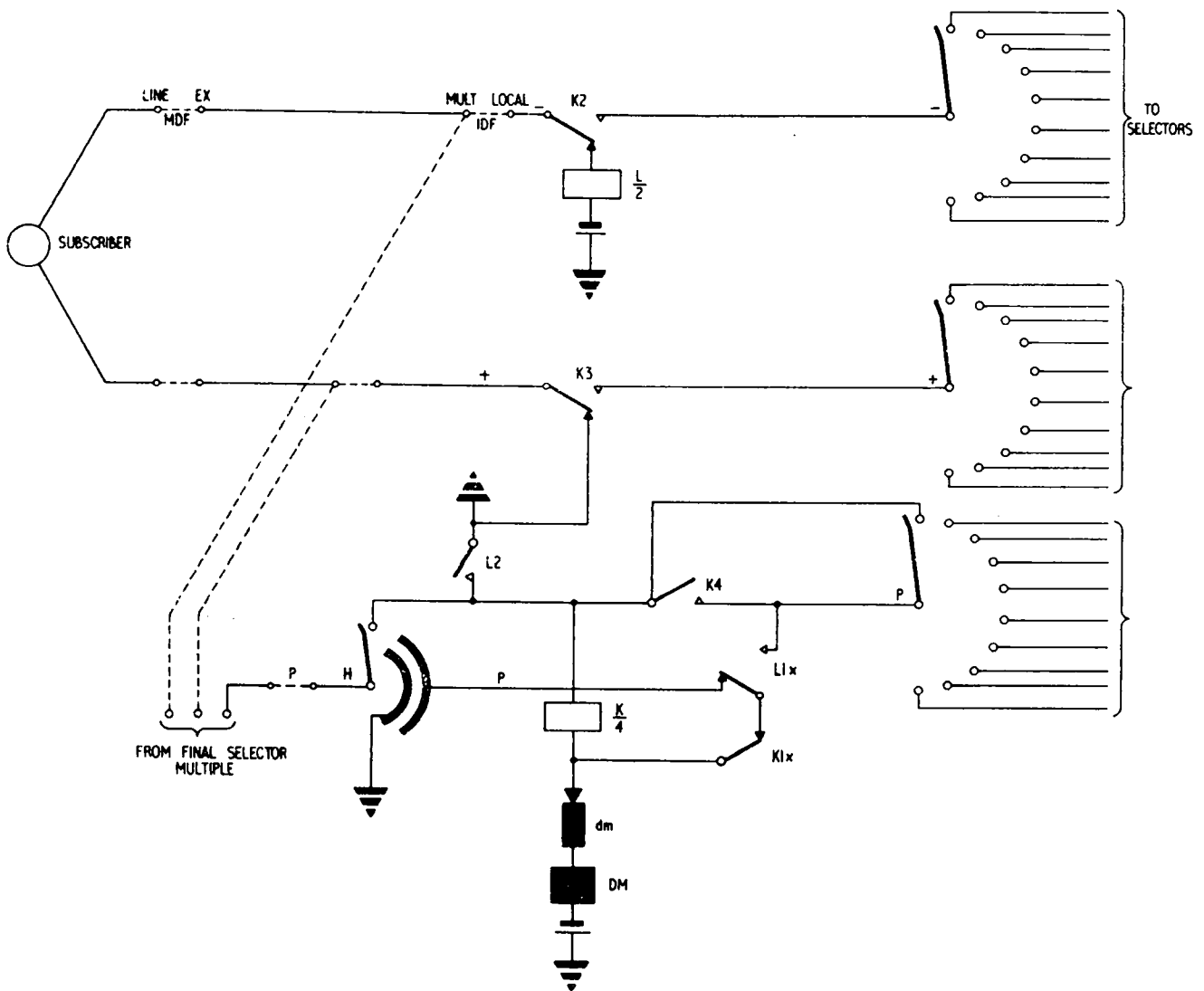
67. Obviously cases will arise where a caller will be unable to find a free selector within a group, in this case 'Busy' tone will be returned to the caller and he will have to try again at a later time. There is also the possibility that a subscriber may dial a number which is not allocated to a subscriber, in which case the 'Number unobtainable' tone will be returned to the caller.

EXCHANGE CIRCUITS

GENERAL

68. The general principles of auto working have been described in the preceding pages. It is now proposed to go through the various circuits, used in the switching stages, to give the facilities enumerated in para 14 and 15.

69. It is apparent that a comparatively high energising current is required to operate the electromagnet of a selector and so the first requirement is for a line relay which will respond to the loops and disconnections given by the subscribers telephone and so initiate the switching operatives in the exchange. The relay most commonly used in this position is the type 600, shown in Fig 21 as $\frac{1}{2}$.



5181/20

Fig 21 - Subscribers line circuit using hunters

SUBSCRIBERS LINE CIRCUIT
(Fig 21)

70. Fig 21 illustrates a subscribers line circuit using hunters. The exchange battery shown in the drawing is usually of the order of 50 volts, derived from secondary batteries. The MDF (Main Distribution Frame) and the IDF (Intermediate Distribution Frame) are necessary as in manual exchanges to provide convenient, flexible interconnections between the incoming lines and the exchange equipment.

71. The uniselector shown has four arcs; three of these arcs (the +, - and P corresponding to tip, ring and sleeve in a manual exchange) have 25 contacts; the 4th one, known as the homing arc (H) has one contact and two solid metal arcs covering the space of all other contacts. The P and H wipers are of the bridging type. All wipers normally rest on the 1st contact of the arc, this is the home position. Busy condition is indicated by an earth on the P wire. Free condition is indicated by a free P wire, ie, neither earth nor battery applied.

Outgoing call

72. When the subscriber lifts his handset to make a call he completes a d.c. loop for relay L via K2, subscriber own telephone K3 and earth. Relay L operates, contact L1 short circuits relay K4 via K1, L1 (operated) P wipers and home contact. L2 is not operated at this instant but later it connects earth to the home contacts of the P arc and the H arc.

73. The earth is extended through the homing wiper to the P wire at the final selector multiple and busies the subscribers line to incoming calls. The same earth applied to the home contact of the P arc is extended via the wipers, L1, K1, dm, DM and operates the driving magnet of the hunter.

74. The armature of the drive magnet causes the pawl to engage in the next tooth of the ratchet wheel and also breaks the springs, dm; dm operated breaks the drive magnet circuit, the armature restores to normal, the action of the pawl moves the wipers to contact No 2 ie, to the first contact feeding the selectors. The dm springs re-make. The H wiper is now bridging the two homing arcs and earth is extended to the P wire of the FINAL selector multiple and will be retained as long as the wipers are off the home position, ie, 'off normal', so guarding the circuit against intrusion by incoming calls.

75. The P wiper is now resting on the first contact leading to the selectors. If the selector is already engaged, ie busy, there will be an earth on its P wire. This earth will short circuit relay K which now has earth on both sides of its operating coil.

76. The circuit for DM is completed through dm, K1, L1 and earth on P wire; the driving magnet re-operates and rotates the wipers to the next contact on the arc. Should this contact be busy the magnet will operate once more and step the wipers to the next contact and will carry on stepping until the P wiper encounters an outlet which is not busy, ie, no earth on the P wire. There is then no earth and consequently no circuit for the drive magnet and the stepping action ceases. Under these conditions relay K is no longer short circuited and operates via the DM coil and L2 to earth. DM itself cannot operate on this circuit because of the resistance of the relay coil. K1 disconnects the DM circuit to the P wipers.

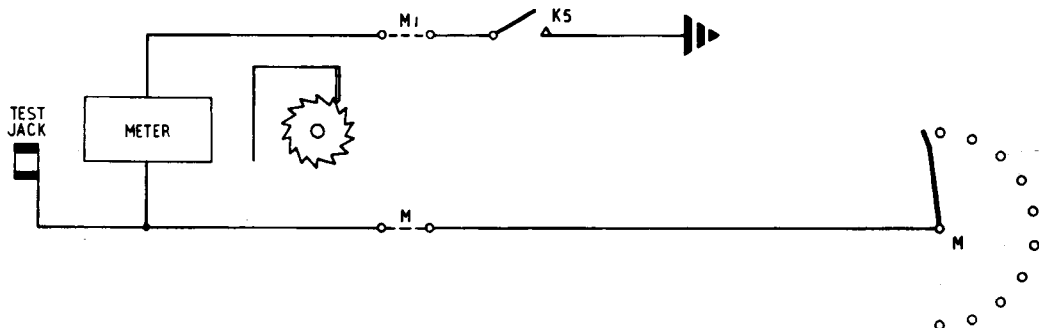
77. K2 and K3 disconnect relay L which is a slow release relay and extend the subscribers lines to the selector which has been seized. K4 extends the earth at L2 (slow release) to the P wire of the seized selector and so marks it busy to prevent it being seized by other hunters.
78. The calling subscribers line is marked busy by earth from the homing arc wiper to the subscribers P wire at the final selector multiple; the circuit is now guarded at each point against intrusion.
79. By the time that relay L releases and L2 disconnects the earth to the P wiper, the selector which has been seized connects an earth to the P wire through one of its own relays. The overlap period of the two earth connections is designed to prevent the circuit being left in an unguarded condition at any time.
80. The selector having been seized, dial tone is returned to the caller and the call is established.
81. When the call is finished, the subscriber replaces his handset and the selector earth on the P wire is removed by relay action in the final selector circuit. Relay K releases and the driving magnet DM now operates via K1, L1, the two homing arcs and wiper to earth. DM continues to operate and drive the wipers until they reach the home position where the circuit of DM is broken by the homing wiper. During this homing period the subscribers line is marked busy by the homing arc earth, H wiper and P wire of the final selector multiple. On return to the home position, this earth is removed and the circuit is free once more to call or to receive calls.

Incoming call

82. When the final selector seizes the called subscribers line it also connects an earth to the P wire. Relay K operates via this earth, H wiper, home contact, K coil, DM. Contacts K2 and K3 disconnect relay L as before to prevent the hunter from stopping and extend the line to the + and - wipers of the hunter which are on the home contacts and thus not connected. On completion of the call, the earth is removed, K releases and the circuit reverts to normal. Note that L1 contacts operate before L2 to short circuit relay K and prevent its premature operation to E at L2.
83. The P wiper is of the bridge type (make before break) to ensure that relay K does not operate while the wiper is moving from one busy contact to another.
84. K1 contacts break before K4 makes to ensure that DM does not operate to E at L2 via K4 and L1 when the K relay operates to seize a free selector.

Metering

85. It is usual to provide a meter in each subscribers line circuit to register the number of calls made on that line. Standard practice is to effect metering when the called subscriber answers. The meter readings are used for traffic analysis or for monitoring purposes. Fig 22 illustrates a simple addition to the circuit of Fig 21 to give metering facilities.



3181/22

Fig 22 - Metering

86. It will be seen that the provision of the meter necessitates an additional arc of contacts on the uniselector and a fourth set of wires which may require to be extended to the final selector. We now have four wires running through the exchange when a call is made, the subscribers two line wires, the P wire and now the M wire. In the circuit shown above, relay K has an additional contact K5 which prepares the cct for the subscribers meter.

87. When the call is established, earthed battery is applied to the M wire from the selector and so operates the meter. In field exchanges this M wire is utilised to give preference and trunk access facilities to selected subscribers and to bar other subscribers from making outside calls.

THE GROUP SELECTOR (100 OUTLET)

(Fig 23)

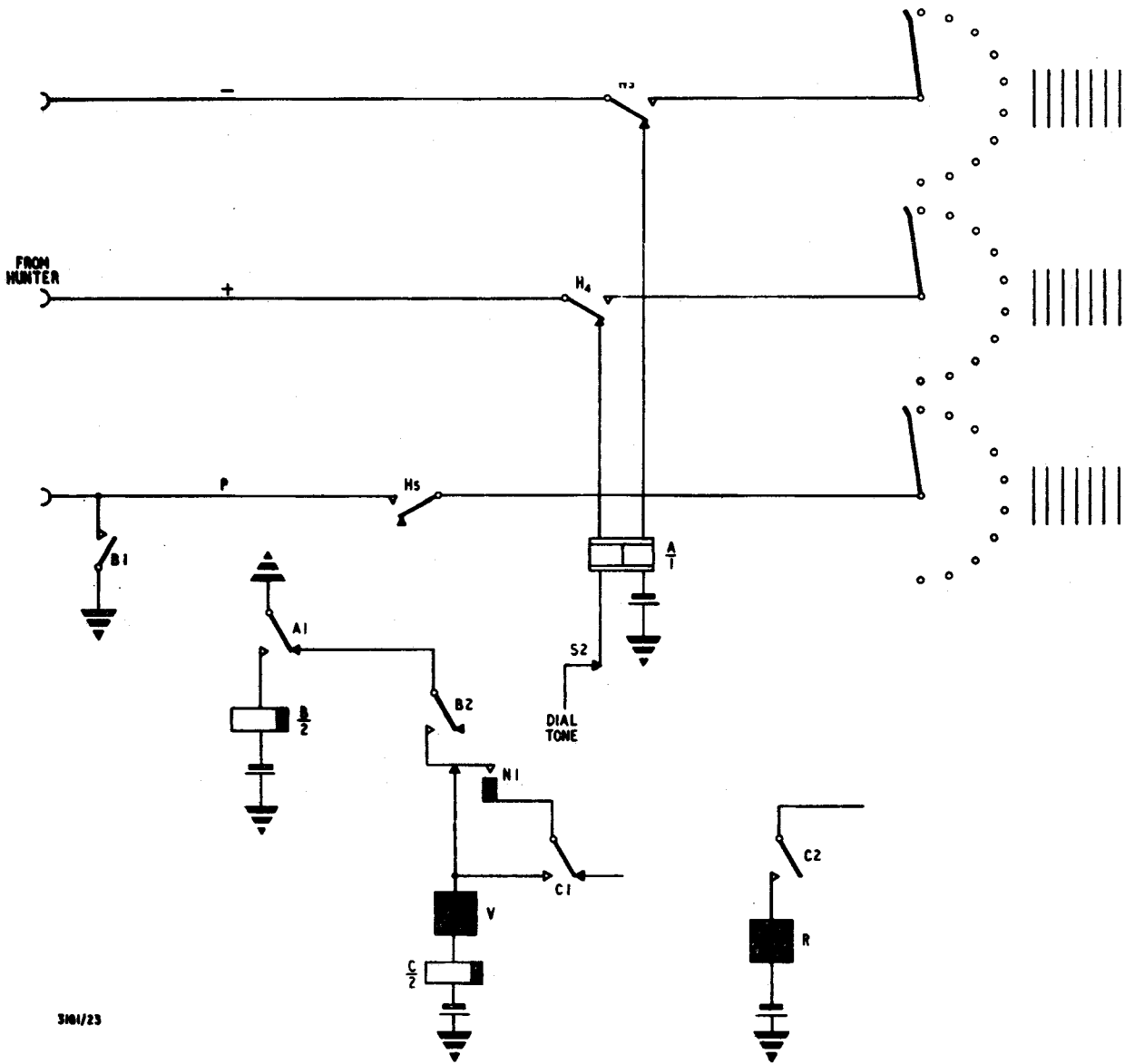
General

88. The group selector is the next stage in the chain of connections. This selector must provide the following functions:-

- a. Guard and hold the connections already established.
- b. Return dial tone to caller.
- c. Respond to 1st train of dial impulses from caller.
- d. Hunt automatically for a free trunk and seize that trunk.
- e. Switch circuit through to the next stage of selection.
- f. Clear bridged apparatus from the lines.
- g. Release on conclusion of call.

h. Provide lamps and alarms to indicate faulty conditions.

89. Fig 23 illustrates in simple form the circuit conditions, after relay K in the line circuit has extended the subs line to the group selector.



3101/23

Fig 23 - Group selector (before dialling)

Pre-dialling state

90. Relay A operates to the subscribers d.c. loop and dial tone is applied through one of its coils as shown. Contact A1, operates relay B and B1 puts a guarding earth on the P wire. B2 prepares a circuit for the stepping magnet V and for relay C.

91. Relay A must respond to the impulse train of signals when the subscriber dials a number, ie, if the caller dials No 3, the d.c. loop will be broken three times and relay A must release three times accordingly. Relay B must NOT follow these impulses and therefore must be a slow release relay which will hold while the A contacts are following the impulse train, and so retain the guarding earth on the P wire.

92. Relay C is also a slow release relay, (release time 120 ms approx) whose function is to prepare a circuit for the rotary magnet so that the selector can commence its hunting action after the receipt of the first impulse train.

Impulsing

93. On receipt of the first break signal from the line, relay A releases. A1 completes a circuit for the vertical electro magnet V and relay C via N1 springs (not yet operated), B2 still operated, A1 released and so to earth. The drive magnet operates and steps to level 1. Relay C operates in series with V and C1 completes an alternative path for the drive circuit via the N1 verticle off-normal springs which are now 'off normal' with the selector operated. Contact C2 prepares a circuit for the rotary hunting action of the selector.

94. The break signal lasts for 67 ms approx and is followed by a 'make' period of 33 ms. Relay A operates to the 'make' signal, A1 disconnects the drive circuit and re-makes the circuit for relay B thus keeping it energised. Relay C remains operated during the period by virtue of its slow release design.

95. Succeeding breaks and makes of the subscribers dial impulse springs cause the above actions to be repeated as described until the end of the impulse train.

96. When impulsing has finished, relay A operates, A1 holds relay B and the initial drive circuit is broken. After 120 ms approx relay C releases, C1 opens the drive circuit and prevents any further action of drive magnet V. C2 contacts prepare a circuit for the hunting action to find a free final selector.

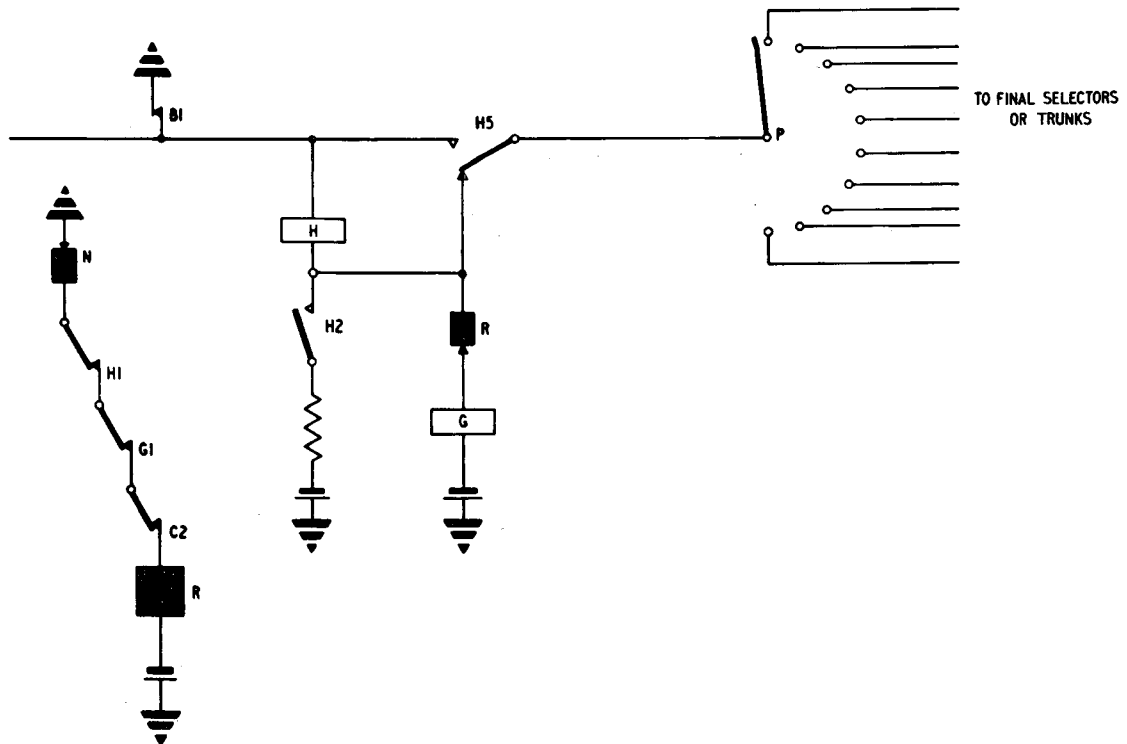
Hunting and testing

(Fig 24)

97. When the first impulse train is finished the selector wipers are resting on the required level and must now search through the level to find and seize a free final selector which will respond to the next two digits and connect to the required subscriber.

98. With the C relay released, contact C2 completes a circuit for the rotary magnet R. The wipers move to the first outlet of the bank. The R springs close and a test circuit is completed for relay G from earthed battery, R spring, H5, P wiper. If this outlet is engaged there will be an earth on the appropriate P wire. Relay

G will operate to this earth and G1 contacts will break the drive circuit. With the rotary magnet released, the R springs will open and relay G will release. Contact G1 will again complete the magnet circuit and the wipers will be moved to the next outlet. Should this outlet be busy the stepping action will be repeated until a free outlet is found and there is no earth to which relay G can operate.

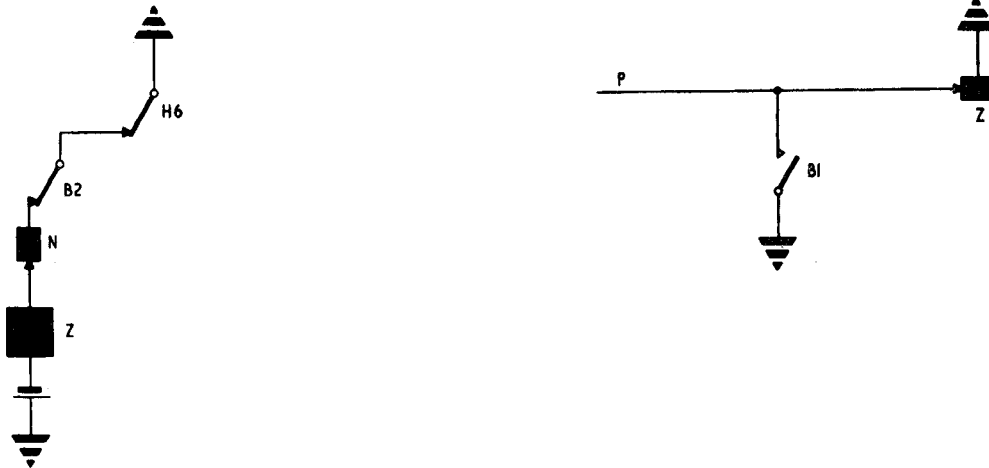


SIB/24

Fig 24 - Hunting and testing for free circuit

99. While the P wiper is contacting engaged outlets the H relay is short circuited by earth on each side of its coil. When a free outlet is found, relay H operates from earth at B1 through relay G to battery. The relays are designed so that H can operate through G, but G cannot operate through H.

100. With relay H operated, H1 breaks the drive circuit, H2 locks relay H and makes it independent of the R springs. Contacts H5, H4 and H3 disconnect relay A from the line and extend the subscribers line to the next stage of selection which in turn puts a guarding earth on the P wire and maintains an alternative circuit for relay H when relay B releases removing earth at B1.



3181/25

Fig 25 - Release circuit

The release circuit
(Fig 25)

101. At the conclusion of the call the guarding and holding earth is removed from the P wire and relay H releases. Contact H6 closes the circuit for the release magnet Z and the selector restores to normal.

102. The N contacts are made while the selector is off normal and break when it restores to the home position. The Z contacts are activated during the release period and maintain a guarding earth on the P wire to prevent the selector being seized whilst releasing.

103. The battery supply to the release magnet is fed via an alarm circuit which will operate if the shaft does not restore to normal in a reasonable time.

PG alarm (pre-2000)
(Fig 26)

104. A fault condition (eg short circuit, earth on wire, etc) in the preceding apparatus including the subscribers line could seize a selector and activate it to the pre-dialling state. It is therefore necessary to provide visual indication of such an occurrence. This can be done as shown in Fig 26. The lamp gives visual indication and the contacts of the alarm relay can be used to operate an audible alarm after a suitable time delay to allow normal operation of the selector. The alarm circuits release when relay A releases.

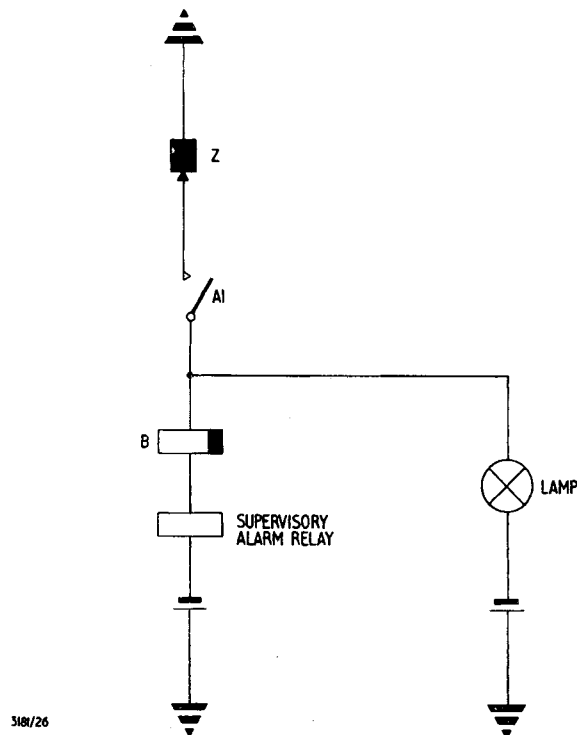


Fig 26 - PG alarm circuit

THE 2000 TYPE GROUP SELECTOR
(Fig 27)Pre-dialling state

105. When the d.c. line loop is extended from the preceding circuits relay A operates:-

- a. A1 operated removes the short circuit from relay B which now operates to earth at N2.
- b. B1 operates and locks relay B to its own earth.
- c. B2 operates relay C via H5 and the two windings of the relay.
- d. B3 puts a guard earth on the P wire to guard the connections already established.
- e. B4 operates the alarm light to indicate selector has been seized.
- f. Relay C prepares a drive circuit for the vertical magnet V through C1 and NR4 so the circuit is ready to operate when A releases for the first break impulse.

- g. C3, C5, C6, extend the -, +, and P wires to the selector.
- h. NR2 and NR3 hold relay A when this changeover takes place.
- j. C4 prepares a circuit for relay H via B5 and N1.

The conditions now are, relays A, B and C operated, relay H not operated.

Impulsing

106. The first break signal in the impulse train releases relay A:-

- a. A1 puts a short circuit across relay B which makes it slow to release so that relay B holds while A is responding to the impulse signals.
- b. The same short circuit provides a path to earth for the V magnet, which operates and steps the wipers to level 1.
- c. The selector is now off normal and springs N1, N2, N3 change over.
- d. N1 completes the circuit for the 500 Ω coil of relay H to earth at C4.
- e. N3 disconnects the alarm lamp.
- f. H1 completes a holding circuit for relay H via C6 and earth at B3.
- g. H2 completes a short circuit of the 700 Ω of relay C via the NR1 springs and makes it slow to release.
- h. H5 breaks the original operate circuit of relay C which now holds on its 5 Ω winding during the impulse train.
- j. H4 prepares a circuit for the rotary magnet R.
- k. H3 removes B4 earth from the P wiper.

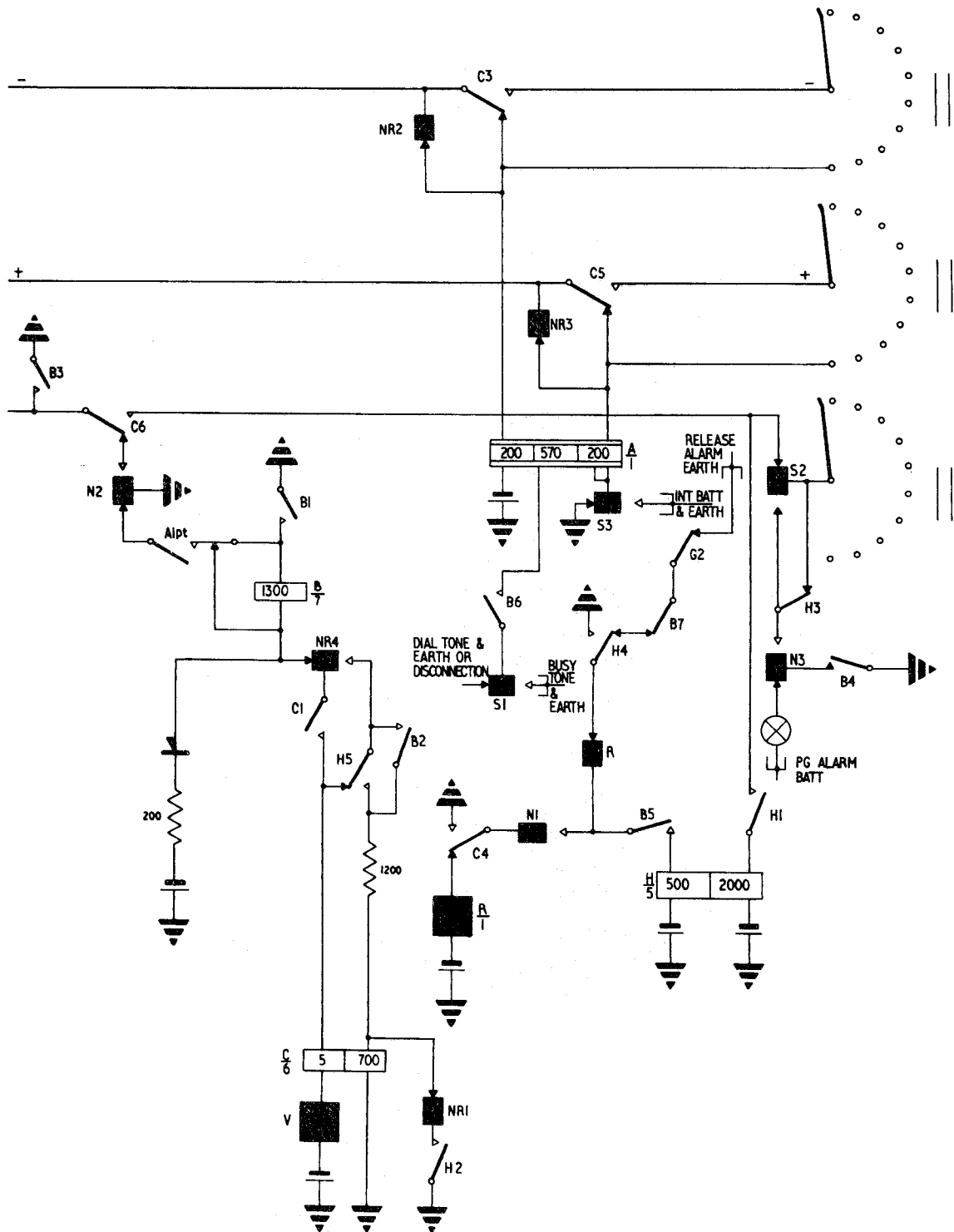
107. Succeeding impulses cause relay A to release and V magnet to operate until the end of the first impulse train (1st digit dialled). The wipers have been raised to the required level and must now begin their rotary action to hunt for and seize a free trunk.

108. Relay C which has been holding during the impulse train on its 5 Ω coil, now releases and at C4 completes a circuit for the rotary magnet R. C6 disconnects B3 earth from the P wipers.

109. Conditions at the end of the first impulse train are, relays A, B, H, operated, relay C released.

Hurting and testing

110. The R springs are operated mechanically by the action of the rotary magnet armature. When the armature is released and at rest the R springs make; they break as the armature nears the end of an operating strike and remain at break until the armature has nearly completed its release action when they make once more.



5181/27

Fig 27 - Circuit for 2000 type group selector

111. When C⁴ completes the rotary magnet circuit, as already described, the magnet operates and the wipers are moved on to the first bank contacts, the R springs open and break the magnet circuit and the NR springs operate.

112. If the first outlet is engaged there will be a holding earth on the P wire which holds relay H in the operate condition. The R springs remake and again complete the magnet circuit, the selector steps and the wipers are moved to the next outlet. If this outlet is engaged, the same action takes place and the wipers continue stepping until they encounter a free outlet.

113. When the wipers reach a free outlet there is no earth for the 2000 Ω winding of relay H, the circuit for the 500 Ω winding is broken by the R springs and so relay H releases:-

- a. H⁴ breaks the magnet circuit and prevents further stepping when the R springs make.
- b. H³ puts a guard earth on the seized P contact from N³ and B⁴.
- c. H⁵ re-operates relay C from earthed battery at V, B² and 100 Ω winding.
- d. C locks in the operate condition through C¹ and NR⁴ operated.
- e. Contacts C³, C⁵, C⁶ now extend the +, -, and P lines through to the seized outlet and release relays A and hence B.
- f. C⁴ re-operates relay H through its 500 Ω winding, B⁵ and N¹.
- g. H¹ locks relay H via earth on the P wire, this earth now being extended from the seized selector.
- h. H⁵ holds relay C operated when B releases, via earthed battery, 5 Ω winding, C¹, NR⁴, H⁵, 700 Ω winding.

114. As the NR⁴ springs are already changed over (Rotary action), the release of relay A cannot cause false stepping of the V magnet.

115. For an established call we now have relays A and B released and relays H and C held.

The release circuit all lines engaged

116. If all ten outlets are engaged the following conditions will apply on conclusion of the tenth step:-

- a. Relay H is held by earth on P wire.
- b. Relay A is held by callers loop.
- c. Relay B is held by B¹.
- d. Relay C is un-operated.

e. The N and NR contacts are operated.

117. The wipers now step to position No 11:-

a. The S springs operate, S1 and S3 return busy tone (and flash ie, visual busy signal to the operator) to the caller via C3 and C5 contacts.

b. S2 disconnects relay H from the P wiper and relay H releases.

c. H5 remakes the circuit for relay C which operates via B2 and then holds via C1, NR4, B2.

d. C4 re-operates relay H and breaks the circuit for R.

e. H holds via H1, C6, B3.

118. Relays A, B, C and H are all held and the wipers are now resting on position 11. Busy tone is being returned via the tone coil of the A relay.

119. The calling subscriber now clears by replacing his handset. This breaks the d.c. loop and releases relay A. A1 short circuits B and (after its time lag) B releases. B2 releases relay C, B5 and B3 release relay H. Contacts C4, H4, B7 and G2 provide a circuit for R to operate and the wipers move to position 12.

120. In this position a mechanical stop prevents the full operation of the R armature and the R springs do not open. This prevents any further rotary action.

121. The wipers are now disengaged from the bank and the notch in the eccentric disc is in line with the comb plate (para 36). The wiper carriage falls to its full extent, below level 1, and rotates to its rest position under the uncoiling action of the restoring spring.

122. The N1 springs release and break the rotary drive circuit. The N2 springs retain a guard earth on the incoming P wire via C6 while the selector is releasing and then restore to normal as the selector comes to rest. The circuit is now ready for another incoming call.

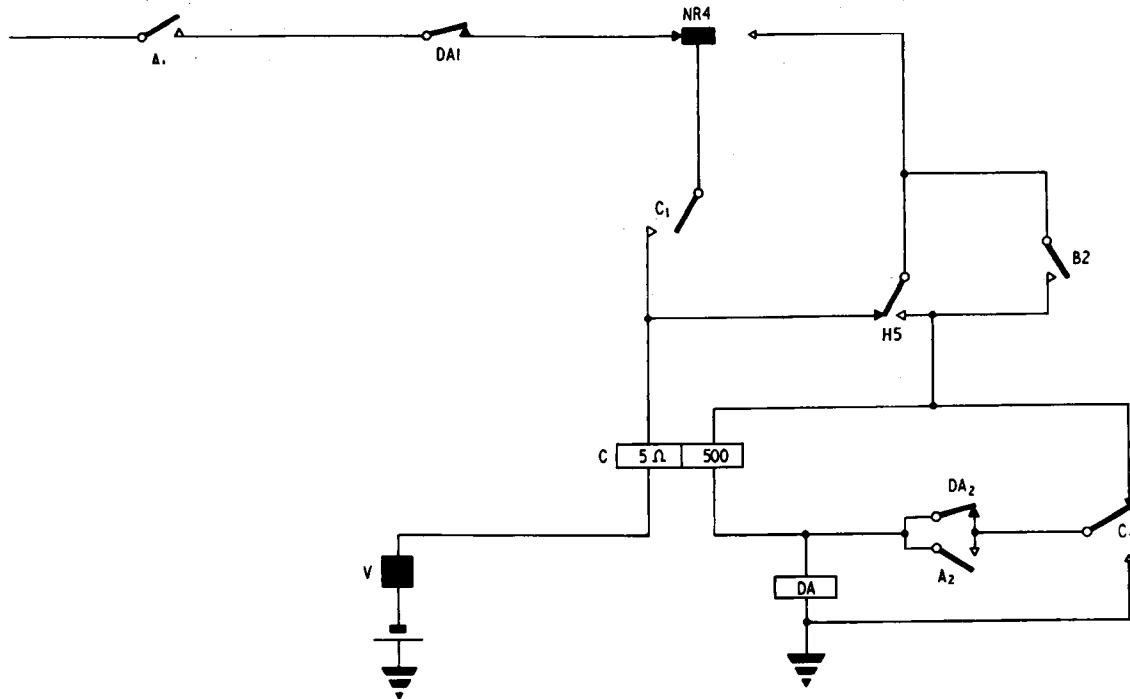
Release circuit, call finished

123. When a call is established, relays A and B are released, C and H are held. When the call is finished the calling subscriber replaces his handset and breaks the d.c. loop. This releases a relay in the final selector and the earth is removed from the P wire.

124. Removal of the earth releases relay H. H4 prepares an alternative rotary drive circuit via B7 and G2. H5 releases relay C. C4 completes the drive circuit for R via N1, R, H4, B7, G2 and the wipers step to position 12 and then restore to normal. C6 maintains a guard earth from N2 while the selector is restoring. C3, C5 disconnect the - and + wipers. All relays are now released, the selector is at rest and ready for another call.

The alarm circuit

125. The lamp will light during the pre-dialling phase when relay B operates. When a number is dialled, the selector operates and the N3 springs break the lamp circuit, indicating that the call is proceeding normally. The lamp will remain alight if the caller fails to dial or if there is a fault on preceding apparatus or on the subscribers line.



3181/28

Fig 28 - Digit absorbing circuit

Digit absorbing
(Fig 28)

126. In certain circumstances it may be necessary to employ a circuit which will prevent the selector from responding to the first digit dialled, but allow it to respond normally to other digits: for instance, we may require to operate small (normally two digit) exchanges ie, less than 100 lines with direct dialling to larger exchanges (up to 1000 lines) and to use a common system of numbering. The small exchange requires only two digits to effect local selection and we must therefore arrange to absorb the extra digit on such calls if redundant switching is to be avoided. This can be done by utilising an extra relay (and extra contacts on A and C relays) as shown in Fig 28.

Note: The requirements for discrimination between trunk and local calls are not considered here.

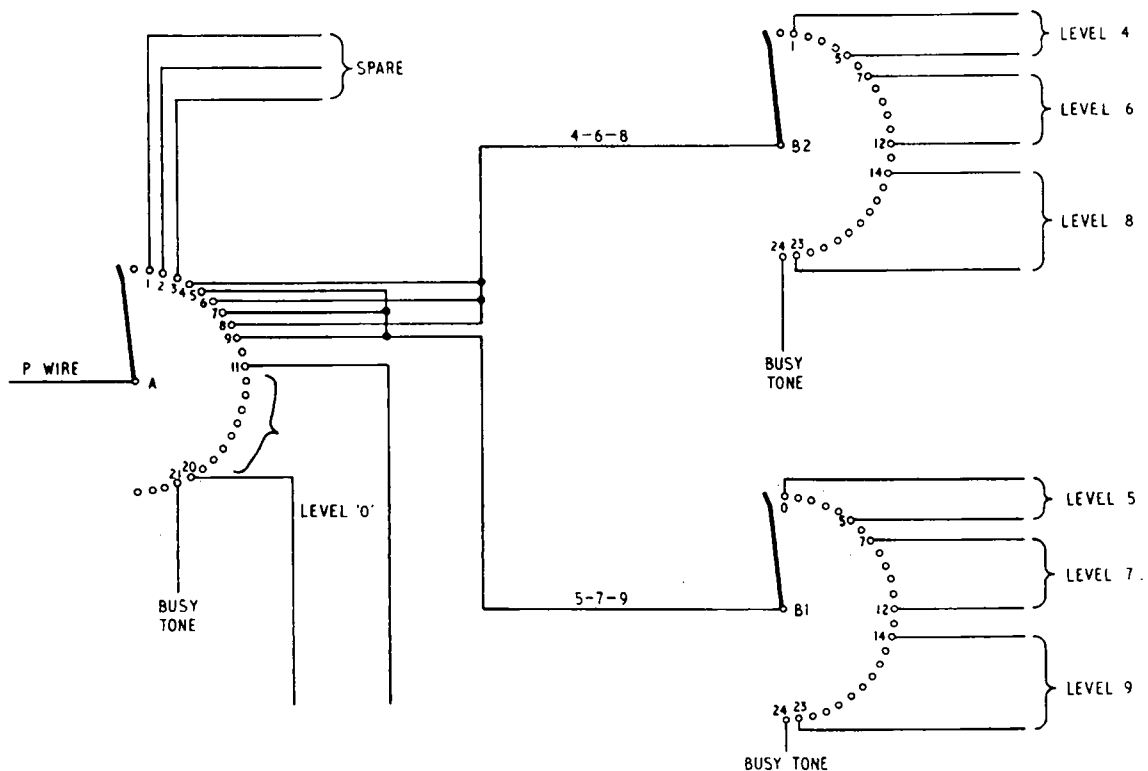
127. When the call is extended to the selector, relays A and B operate as before. Relay DA operates via earthed battery, V, 5Ω coil, H5, B2, C7, A2 to earth. DA1 breaks the magnet circuit, DA2 opens, leaving relay C short circuited by C7 and A2.

On receipt of the 1st break impulse relay A releases:-

- a. A1 makes but the magnet circuit is broken by DA1.
- b. A2 opens to remove the short circuit from relay C and C operates.
- c. Contact C7 prepares a short circuit for DA when A2 makes after the first break impulse. This short circuit makes DA slow to release and holds DA operated during the first impulse train, so preventing the magnet from stepping.

128. On completion of the first impulse train:-

- a. A2 opens and DA is released.
- b. DA2 completes a short circuit across DA and prevents it operating to the second impulse train.
- c. DA1 is now made and the magnet V responds to the makes and breaks of A1 for the second impulse train.



3181/29

Fig 29 - Group selector for 100/150 line field exchange

Group selectors for field use
(Fig 29)

129. The two motion selector is not used in the field as it is not suitable for use in mobile role. Uniselectors are used instead. The basic principles already described still hold good, the hunting arrangements are slightly different and are illustrated in Fig 29 which shows the method adopted in the 100/150 line field exchanges using two uniselectors A and B.

130. In practice the A and B uniselectors have nine arcs of 25 contacts each. Four of the A arcs are required for the +, -, P and M wires respectively. Eight B arcs are required for hunting on the required level. The other arcs are used to control the switching required. Fig 29 shows the path for one wire only.

131. The A selector responds to the first digit dialled and steps to the appropriate contact. In the drawing, levels 1, 2 and 3 are spare and are connected to spare level circuits which will return NU tone to a caller.

132. Should the caller dial No 4 or No 5, the B magnet will be brought into action and the B wipers will search B outlets 1 to 5 for a free final selector.

133. The B2 arc provides five outlets for contact No 4 on the A arc whilst B1 arc provides five outlets for contact No 5 on the A arc.

134. If the first number dialled is above 4 or 5, the other arcs of the A and B selectors will cause the hunting action of the B wipers to continue their movement and search outlets 7 to 12 on B2 if 6 is dialled or outlets 7 to 12 on B1 if 7 is dialled. Similarly the B2 wiper will hunt over 14 to 23 if 8 is dialled and the B1 wiper searches over 14-23 if 9 is dialled.

135. In each case the B wipers must hunt over the appropriate part of the arc and seize a free final selector during the inter digital pause, approx 500 ms. It is therefore necessary to ensure that at the end of the first impulse train the B wipers are correctly positioned on the sections of the arc which provide outlets for the first digit dialled.

136. Thus if No 9 were dialled, on the 6th break impulse the B wipers position themselves on contact 6, ready to search outlets 7 to 12; on receipt of the 8th impulse they move to position 13 ready to search outlets 14 to 23.

137. If 0 dialled, ie, ten impulses, the A wiper moves to position 10 and then searches outlets 11 to 20 on the A bank for a free outlet to the manual exchange, ie (single digit dialling).

THE FINAL SELECTORGeneral

138. The last selector in the chain of connections, which provide access to the called subscriber, is known as the connector, or final selector. Where two motion selectors are in use the vertical action and the subsequent rotary action are both impulse controlled. The wipers are stepped to a definite outlet, in accordance with the number dialled. The functions of the final selector are as follows:-

- a. Guard and hold connections already established.
- b. Step the wipers vertically to the required level, on receipt of the tens digit impulse train.
- c. Rotate the wipers under the control of the units impulse train.
- d. Test the called subscribers line.
- e. If free:
 - (1) Connect guard and holding earth to the P wire.
 - (2) Connect interrupted ringing current to called subscriber.
 - (3) Connect ring tone to the caller.
- f. Disconnect ringing and ring tone when the called sub answers.
- g. Reverse the earthed battery and earth connections to the negative and positive lines of the incoming trunk for metering or supervisory purposes.
- h. Provide a transmission bridge.
- j. Release itself and all other connections when the caller clears.
- k. Provide its own guard while releasing.
- l. Provide supervisory and alarm signals.
- m. If the called number is engaged, return busy tone and flash to the caller.

139. These operations are detailed in the following paragraphs as a preliminary to considering the final selector circuit as a whole.

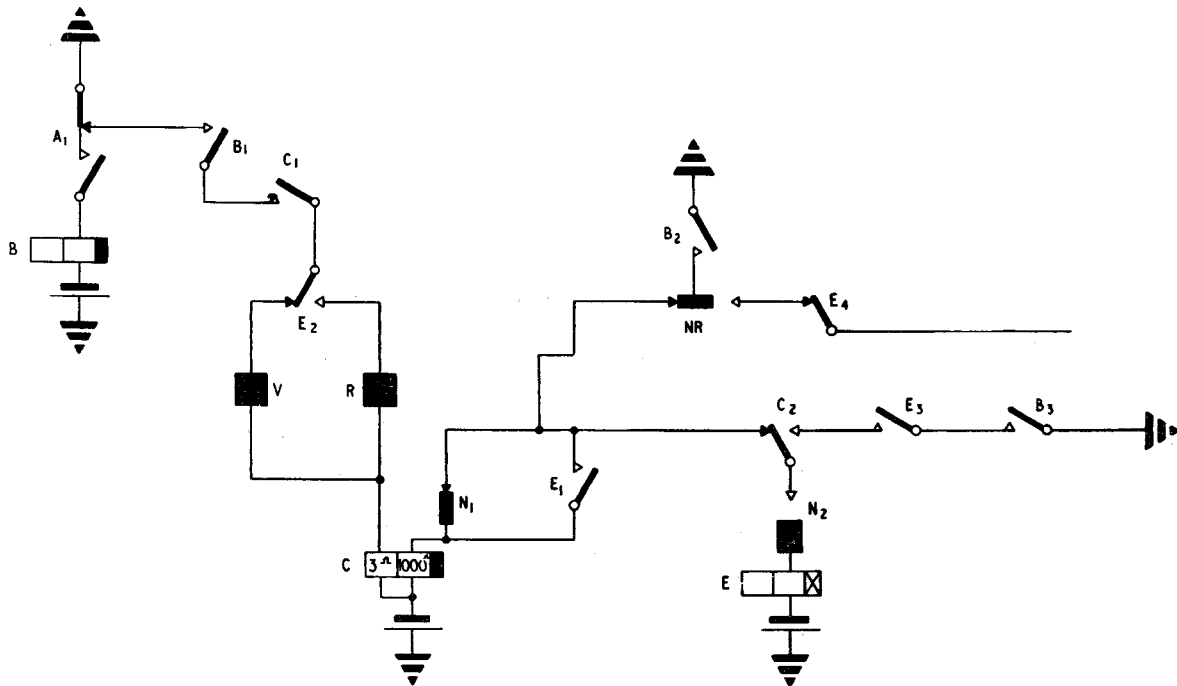
Impulse controlled selector
(Fig 30)

Pre-dialling state

140. The line loop, extended from previous stages, operates relay A as before and A1 operates relay B. B1 prepares a circuit for vertical magnet V. B2 operates relay C via N1, NR, B2 to earth. C1 further prepares the circuit for V while C2 prepares a circuit for relay E. So, before dialling commences, relays A, B and C are operated, relay E is not operated.

First impulse train

141. On receipt of the 1st break impulse, relay A releases and A1 completes the V magnet circuit via 3Ω coil, V, E2, C1, B1, A1 to earth.



3181/30

Fig 30 - Impulse control of selector

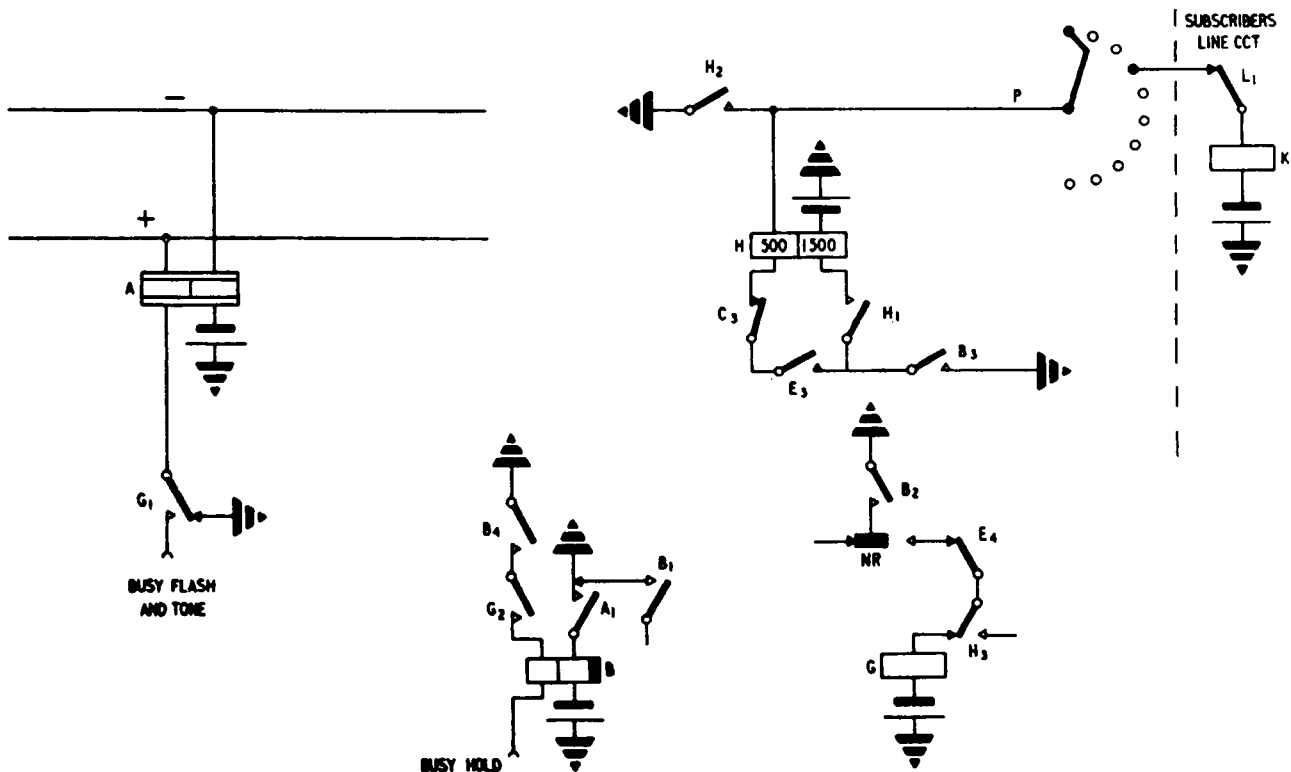
142. The magnet operates and the wipers are stepped to level 1. Springs N1 and N2 are operated, relay C holds on its 3Ω winding. Further break impulses will cause V to operate and step the wipers to the required level. At the end of the impulse train relay A is operated, B is operated and C released. C2 contact released, now operates relay E via N2, C2, NR, B2.

143. Contact E1 operates relay C via NR and B2. Contact E2 changes the magnet circuit over from the V magnet to the rotary magnet R. Relay E is now held by the circuit N2, C2, E3, B3.

Second impulse train

144. When A releases this time, A1 completes a circuit for R via 3Ω coil, R, E2, C1, B1, A1. The magnet responds to the impulses and the wipers are stepped round to the selected outlet.

145. The NR springs are now changed over but relay C holds, as before, on its 3Ω winding during the impulse train. It then releases and breaks the magnet circuit at C1.



348/31

Fig 31 - Testing circuit (free)

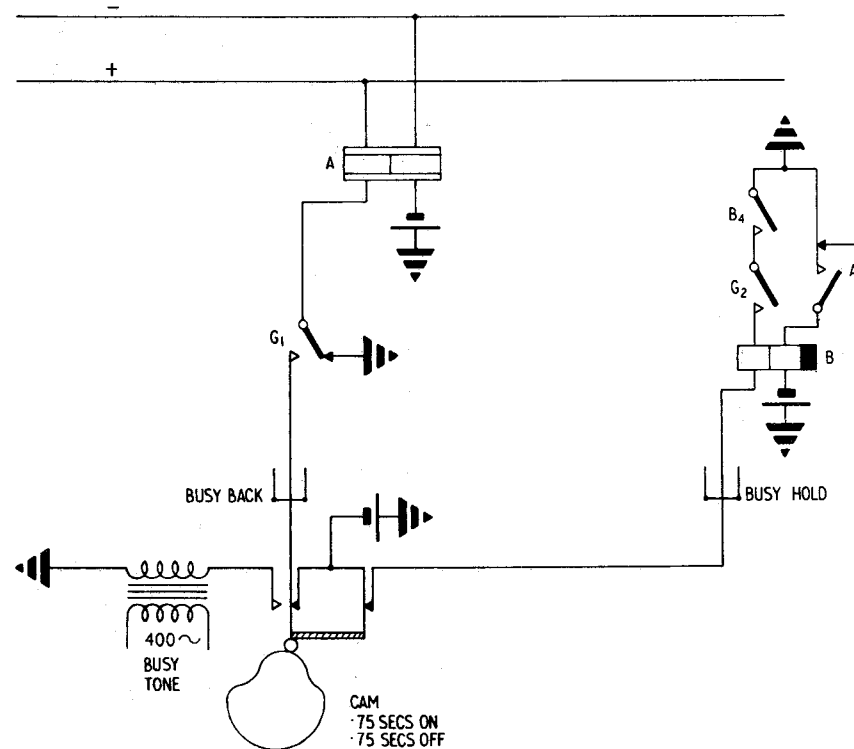
Testing circuit (free)
(Fig 31)

146. When relay C releases, at the end of the 2nd impulse train, it completes a test circuit for relay H from the P wiper, 500Ω coil, C3, E3, B3 to earth. (Relay E, though disconnected by C2 is slow to release and the E3 contact is still made at the instant of testing).

147. If the line is free, battery is extended from the subscribers line circuit via relay K and L1 to the P arc contact and relay H is operated.

148. H1 puts a holding earth on H to cover the release of E3. H2 puts a guard and holding earth on the P wire and operates relay K in the subscribers line circuit. This in turn disconnects the subscribers line relay from the line.

149. Other contacts of relay H prepare circuits for applying ringing current to the line. H3 disconnects relay G.



3181/52

Fig 32 - Testing circuit (engaged)

Testing circuit (engaged) (Fig 31, 32)

150. If the subscriber is engaged there will be no battery on the P outlet to operate relay H. The test circuit is broken by E3 when relay E releases. With H not operated and E released, a circuit is made for relay G via H3, E4, NR, B2.

151. Relay G operates and connects busy signal to the caller via G1 and a winding on the A relay. The busy signal is a tone of 400Hz, interrupted to give .75 seconds on, .75 seconds off.

152. In the off period, ie, the flash, earthed battery is connected via G1 to relay A. With battery connected to both coils of relay A there is no current flow and A releases for the duration of the flash ie, .75 seconds.

153. Relay B has a release lag of approximately 320 ms and therefore to prevent B releasing and severing the connexion, a holding circuit is provided by B4, G2 and battery (busy hold) is applied during the flash period. Fig 32 shows the busy tone and hold arrangements.

156. The ringing current is a.c., interrupted to give .4 seconds on, .2 seconds off. During the off period, an earth is applied to the line.

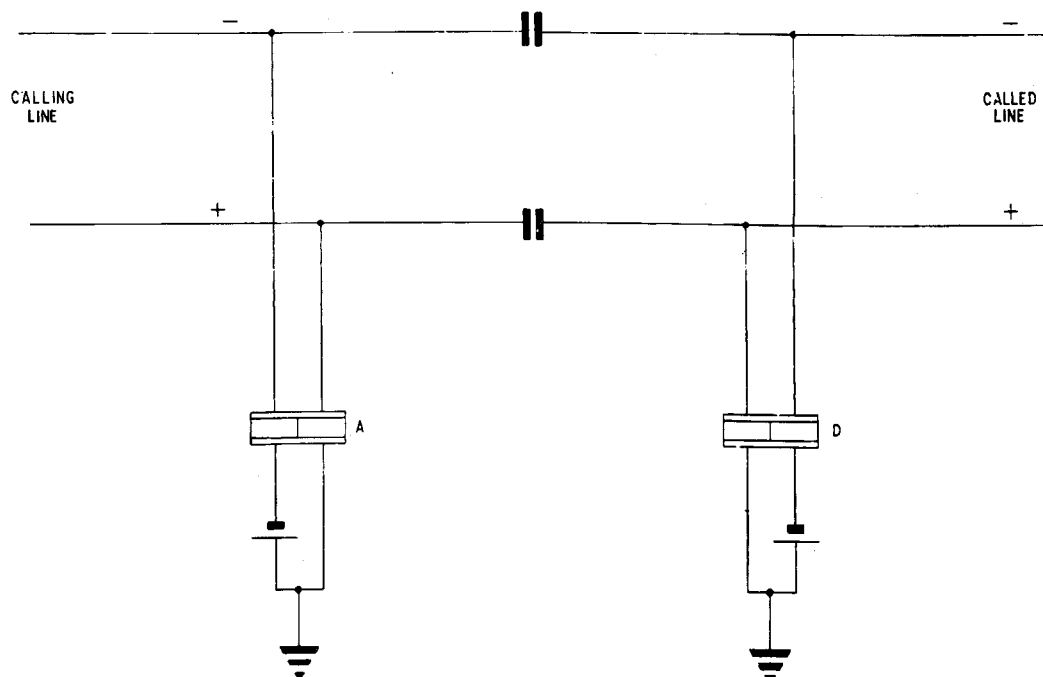
157. While ringing is going on, the subscribers handset is still on its cradle and the only path through the instrument is an a.c. path consisting of capacitor and bell. These offer a high impedance and only a small amount of a.c. will flow.

158. Directly the subscriber answers the call and lifts his handset he completes a low resistance d.c. loop which allows relay F to operate.

159. F1x breaks the short circuit across the second coil of F and the relay locks via H1, E4, NR, B2. This short circuit prevents operation of relay F by H1 until the called subscriber answers the call. F2 and F3 disconnect the ringing current and extend the speech lines to the subscriber.

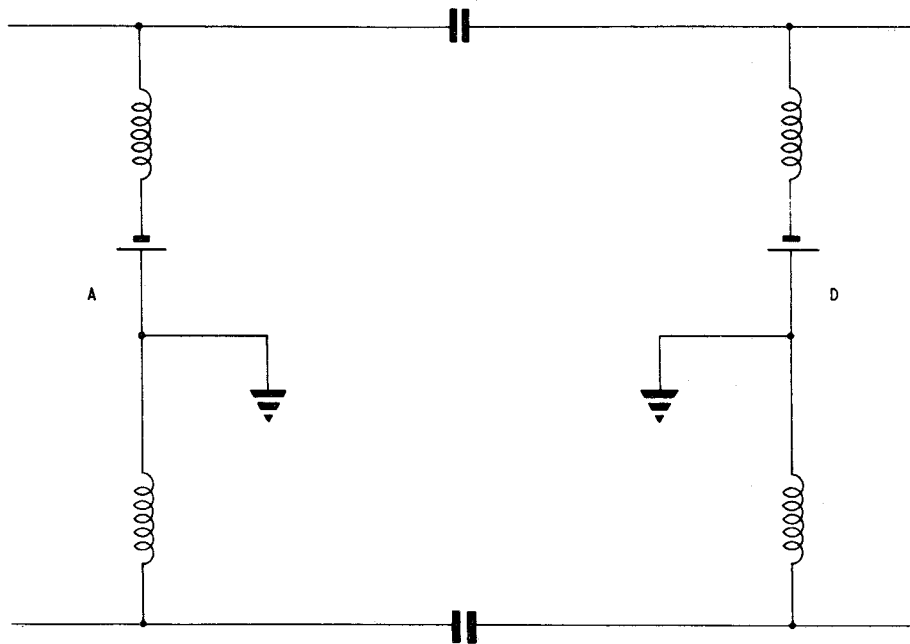
160. Should the subscriber answer during an interruption period, the earth applied to the line from the interrupter will activate relay F via the d.c. loop provided.

161. Interrupted ringing is used for calling because it is found to be much more effective as a signal than continuous ringing. The ring tone informs the caller that the wanted number is being rung.



3181/34

Fig 34 - Simple transmission bridge circuit



3181/35

Fig 35 - Speech current isolation

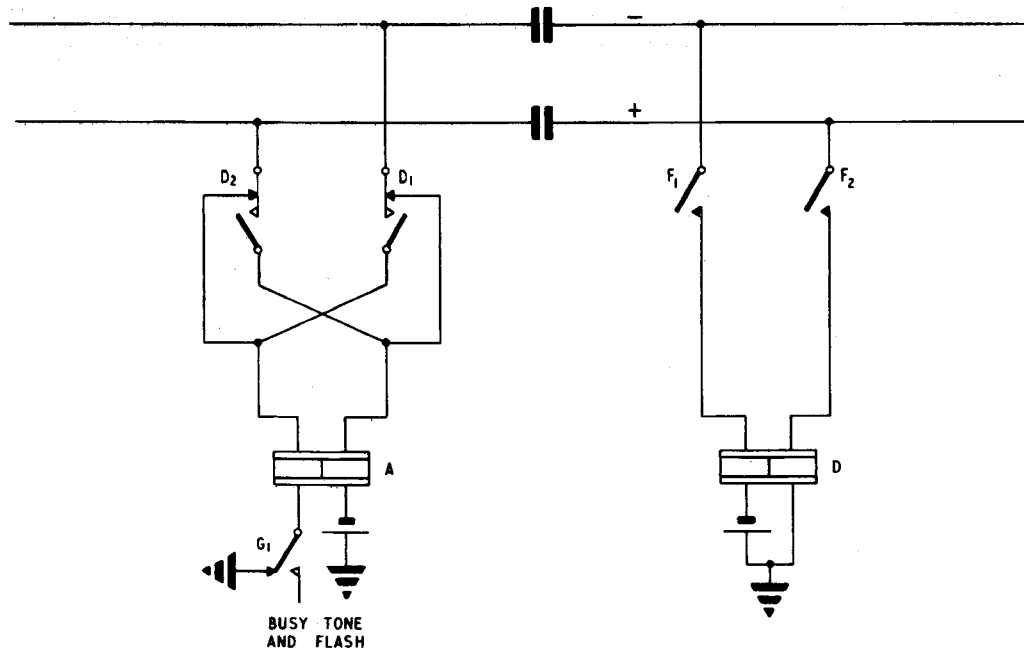
Transmission bridges
(Fig 34, 35, 36)

162. As in the case of CB manual operation, or any equipment using a common power source, it is necessary to guard against overhearing between circuits through the common battery. Isolation of individual speech circuits and separation of speech currents and d.c. is achieved by means of transmission bridges which effectively provide a high impedance battery source for each speech circuit and also independent d.c. loops on called and calling lines. In its simplest form the auto transmission bridge would appear as shown in Fig 34.

163. Relay A is the normal, impulse accepting relay in the calling circuit, in addition to its impulsing function, it also controls the release of all connections established from the caller to the selector.

164. Relay D is brought into circuit when the called subscriber answers and this relay also effects the operation of the calling subscriber's meter.

165. Each relay has two identical coils to maintain line balance. Fig 35 shows how the relay coils are used to isolate the speech currents from the battery, the coils offering high impedance to speech currents, the capacitors offering a relatively low impedance path.



3181/36

Fig 36 - Transmission bridge for final selector

166. Transmission bridges are normally included in the final selector though they may be found elsewhere. Wherever they are placed the following conditions must be met:-

- a. To minimise transmission and impulsing losses all preceding A relays must be switched out of circuit, stage by stage, leaving only the A relay of the bridge connected to the callers line.
- b. This A relay feeds the battery to the callers instrument and controls the release of the connection (junction working is slightly different).
- c. The D relay in the called subscribers circuit must control the metering.
- d. If the bridge is not located in the final selector, arrangements have to be made to repeat the impulse signals to activate succeeding selectors. This is because of the two capacitors.
- e. These capacitors also necessitate arrangements for passing signals for supervisory and metering purposes. Fig 36 illustrates a typical transmission bridge for a final selector.

167. Contacts F1, F2 are open while relay A is operating to dialled impulses. This is to prevent the capacitors charging and discharging and so affecting the operating characteristics of A.

168. When the called subscriber answers, the F contacts make and operate relay D. The contacts of relay D are arranged as shown to reverse the direction of current in the calling circuit, so giving indication that the call has been answered. This reversal can be used to operate the callers meter or to give supervisory signals.

169. If the called line is engaged, D does not operate and the busy signal is returned via one coil of relay A, D2 and the + wire.

Transmission bridge with ballast resistors

170. Fig. 37 shows the coils of relay D connected to ballast resistors. These are used with 50 + 50 ohm, nickel-iron sleeved, relays to give an increased transmission efficiency comparable to that obtained when using a normal 200 + 200 ohm relay without resistors. Nickel-iron sleeved relays are used because they offer a high impedance to speech currents and the impedance is less effected by the flow of d.c. than is the case with normal cores.

Final selector 2000 type (Fig 37)

Pre-dialling state

171. A operates to the line loop when the selector is seized. A1 operates B via the rectifier MRA. B4 locks B, and B1 operates relay C. C1 prepares a circuit for vertical magnet V via NR1, E3, 5Ω coil, C1, A1, B4 to Earth.

First impulse train (Tens Digit)

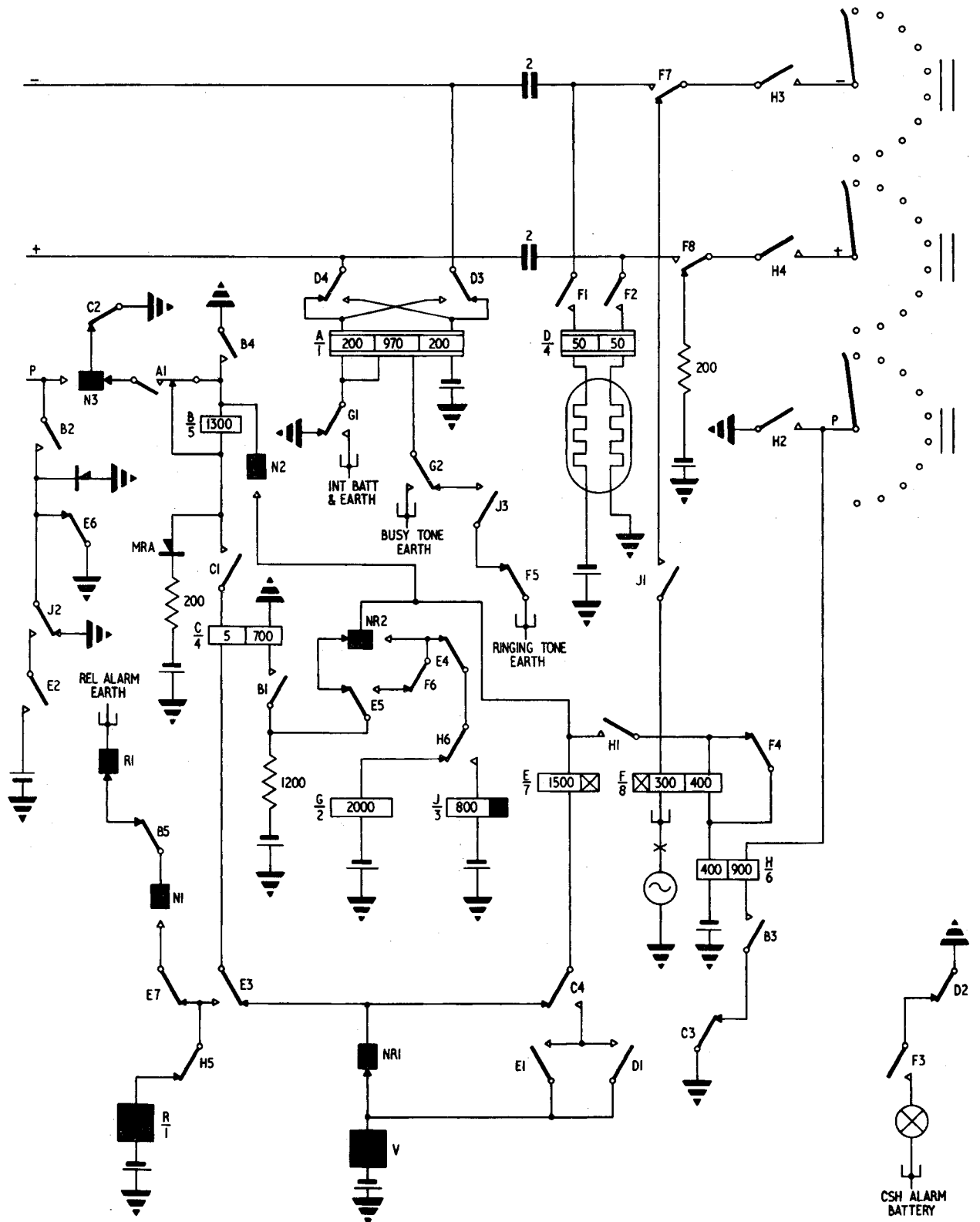
172. A releases to the first break signal of the impulse train and the V magnet operates, stepping the wipers to level 1; subsequent breaks raise the wipers to the required level. The release of A1 puts a short circuit across relay B, making it slow to release so that it holds during the break periods.

173. The movement of the selector operates the spring sets N1, N2, N3. N2 completes a short circuit across the 700Ω winding of C via B4, N2, NR2, E5, B1. This short circuit makes C slow to release and C remains operated on its 5Ω winding during impulsing. When the impulse train is finished C releases; A and B remain operated.

174. Rectifier MRA and the 200Ω resistor are effectively in parallel with the V magnet but have little effect because of the rectifier characteristic.

Final impulse train (Units Digit)

175. With C released, C4 completes a circuit for relay E from earthed battery, V, NR1, C4, E7, N2, B4 and relay E operates. E5 removes the short circuit from C and allows C to operate.



3181/37

Fig 37 - Final selector, 2000 type

176. C4 and E1 now provide a holding circuit for relay E. E3 changes over and prepares a circuit for the rotary magnet R.

177. A releases once again to the break impulse and causes the R magnet to step the wipers round to the required outlet. The initial rotary movement of the selector operates the NR springs. NR1 disconnects the V magnet. NR2 completes a short circuit across the 700Ω winding of relay C, via B1, E5, F6, NR2, N2, B4 to earth.

178. Relay C holds on its 5Ω winding during the impulse train and then releases when A1 breaks the circuit at the end of the train.

179. When C releases, C4 breaks the circuit for relay E which also releases. E has a slow release and the release time is used to test the outlet.

Testing circuit

180. If the outlet is free, there will be no earth connected to the free P outlet from the subscribers line circuit. If engaged, the outlet will have an earth on it, applied by the H2 contact of some other final selector.

181. At the end of impulsing, relay C has released, relay E is disconnected but has not yet released because of its release lag. C3 completes the testing circuit for relay H (via earth, B3, H6, P wipers). If the wanted subscriber is engaged there will be an earth on his P wire and H will not operate. Therefore:-

- a. When E releases, contact E4 operates the G relay (via H6, E4, NR2, N2 B4) and G1 and G2 return flash and busy tone respectively.
- b. E5 removes the short circuit from the 700Ω coil of C4 and allows it to re-operate.
- c. C3 breaks the test circuit of H6 and prevents the possibility of the test relay (H) operating should the wanted subscriber clear down at this time.

182. If the wanted subscriber is free, relay H operates to the battery on the P wire and locks on its other (400Ω) winding via F4, H1, N2, B4. Then:-

- a. H3 and H4 extend the - and + wipers back to the F7, F8 contacts.
- b. H2 applies guarding and holding earth to the P wire to mark the subscriber busy and to operate his K relay.
- c. H6 disconnects relay G and operates relay J when E releases.
- d. J1 applies interrupted ringing current to the called subscriber. (300Ω F coil, J1, F7, H3, Sub, H4, F8).
- e. J3 returns ring tone to the caller. (F5, J3, G2, 970Ω A coil, G1).

183. When the called subscriber lifts his handset to answer the call, he completes a d.c. loop through his own instrument. Relay F operates to this loop on its 300Ω coil:-

- a. F4 opens and the relay locks in series with the H relay circuit.
- b. Contacts F7 and F8 complete the line circuit and disconnect the interrupted ringing.
- c. F5 disconnects the ring tone.
- d. F3 connects the called subscriber held (CSH) alarm circuit.
- e. F1 and F2 connect the D relay to the called subscribers line circuit.
- f. The D3 and D4 contacts transmit the supervisory signal (ie, battery reversal).
- g. D2 disconnects the CSH alarm.

Release circuit

184. When the caller replaces his handset:-

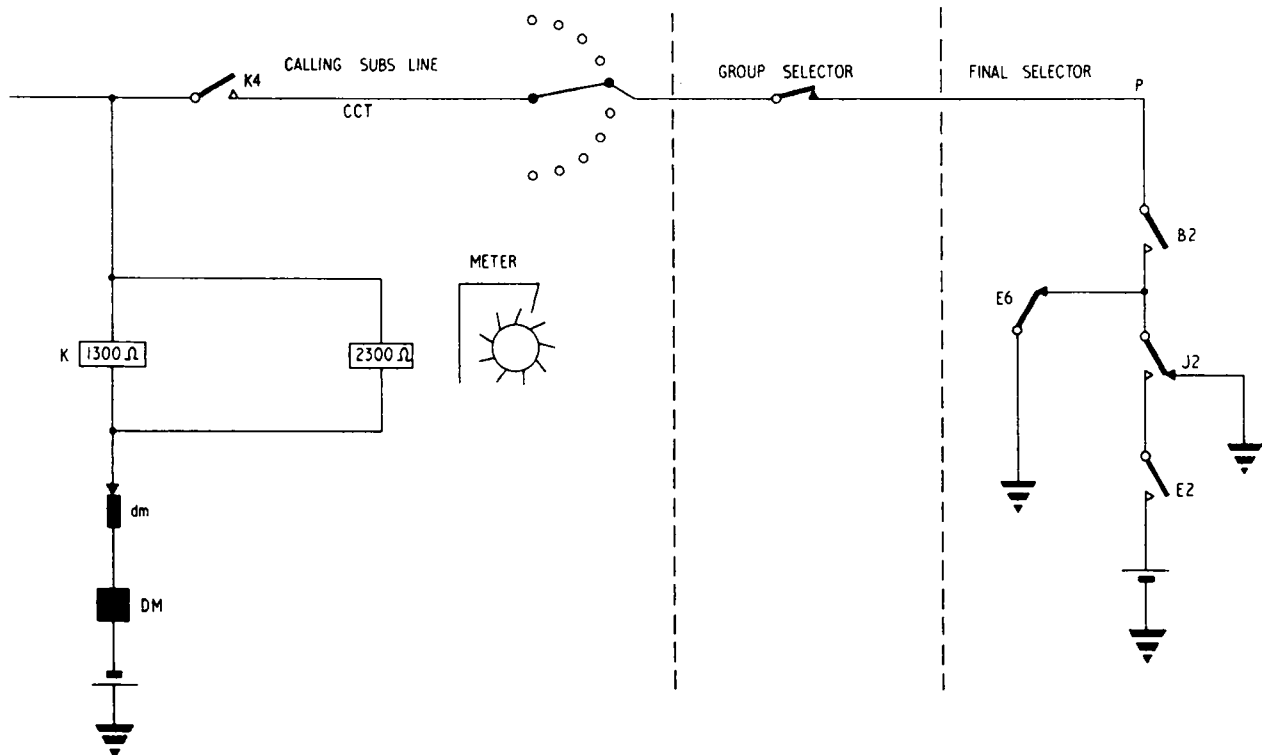
- a. A releases and A1 releases B.
- b. B4 releases F and H relays.
- c. B1 releases C.
- d. C2 puts a guarding earth on the P wire through N3.
- e. H5 and B5 released, complete a self drive circuit for R via the release alarm circuit.
- f. The selector steps to position 12 and then releases.

Called subscriber held alarm (CSH)

185. When a call is established, the following relays are all operated; A, B, C, D, F, H. The CSH alarm circuit is broken by contact D2 when the subscriber answers the call. When the called subscriber hangs up, if the caller fails to clear down, he will hold all the established connections, plus relays A, B, C, F and H, and the called subscribers outlet will be marked engaged even though the called subscriber has replaced his handset. Under these conditions the F3 contact will complete the alarm circuit to give visual and audible indication that the circuit is being held by caller and the called subscriber is unable to receive or make calls.

Booster metering
(Fig 38)

186. When H operates to a free outlet, H6 operates relay J as already described. When the called subscriber answers contacts E2 (slow release), J2 and B2 momentarily apply reversed battery to the P wire in series with the battery at DM to activate the callers meter which will not operate on 50V only. On complete release of relay E, E2 disconnects this circuit and E6 applies earth to the P wire.



5181/58

Fig 38 - Booster metering

Final selection using uniselectors (Fig 39)

187. As in the case of the group selector, small exchanges and military field exchanges (100/150 lines or less) use uniselectors for final selection. Two uniselectors are required, to respond to the tens digit and the units digit.

188. In this application the tens selector responds to the first digit received at the selector. This of course is the 2nd figure dialled, the 1st or hundreds digit being used to activate the group selector. Various arcs and wipers on the tens selector are used to drive the units selector wipers in steps of 10.

189. The units selector then responds to the final impulse train and steps over the selected section of its arc to seize the outlet required. Thus, if the number dialled is 623:-

- a. The group selector responds to the 1st digit dialled and steps to level 6.
- b. Automatic hunting takes place on this level and a free final selector is found.

c. The tens selector responds to the 2nd impulse train, moves to position No 2 and causes the units selector to step to position No 20.

d. The impulse train for figure 3 now operates the units selector and steps it three times to finish on outlet No 23 which is of course connected to subscriber No 623.

190. Fig 39 illustrates the principle of selection as used in the military 100/150 line exchange. Two uniselectors are used, the A selector has five arcs of 25 contacts each, the B selector has eight arcs of 25 contacts but using double wipers to give, in effect four arcs of 50 outlets (see para 20). 24 final selectors are used in this exchange, 24 group selectors and 24 line finders all arranged in groups of three, covering 50 lines in each group.

191. The subscribers are allocated numbers in the 600, 700 and 800 groups as follows:-

600-609)	50 subs))	Total 150 subs
660-699)			
700-709)	50 subs))	
760-799)			
800-809)	50 subs))	
860-899)			

192. The group selector responds to the hundreds digit and the final selector responds to the final two digits.

193. Thus, assume the last two digits to be dialled are 9 and 6. Relay A operates as before to the line loop and in turn operates relays B and C. Break impulses cause A1 to complete the stepping circuit for the tens selector A. On completion of the 6th pulse, the A wipers are all on position No 6.

194. When relay A releases for the 7th pulse, the A2 contacts make and provide a self drive circuit for selector B via, earth, A2, A3 wiper, home contacts of B1, B1 wiper, E1, dm, HS3, B.

195. The B selector steps and continues stepping over the earthed contacts of arc B1 until it reaches outlet No 10 where there is no earth to activate the magnet circuit.

196. On completion of the 8th pulse, earth is extended via wiper A4 to complete the self drive circuit of B and the B wipers move, as before, on the earthed contacts to position No 20.

197. On completion of the 9th pulse, earth is extended via A5 wiper and the B selector continues its self drive to position 30 on arc B2.

198. At the end of the impulse train, the B wipers are on position 30. Relay C releases and operates relay E. E1 opens the self drive circuit of selector B, E3 changes over the impulsing circuit to selector B.

199. B now responds to the final impulse train and steps six times. All the B wipers are now on outlets No 36 which are the outlets for line circuit - 96. Testing and ringing now takes place as described for the 2000 type selector. From the above description it will be apparent that the switching is as follows:-

First digit received	A wipers	B wipers		Connect to line circuits
		Self drive to	Impulse over	
6	Pos 6	Home contact	1-10	61-69 and 60
7	7	10	11-20	-71 -70
8	8	20	21-30	-81 -80
9	9	30	31-40	-91 -90
10	10	40	41-49-0	01-09 and 00

PBX working

200. PBX working can be used on 45 lines in each group of 50, with a maximum of nine lines in any one PBX group. This means that if a group of lines are connected for PBX working, the final selector will hunt for, and seize, a free line within that group, whenever the first line in the group is dialled.

201. Fig 39 shows the outlets 1-9, 11-19, 21-29, etc of the B1, B2 arcs connected directly to earth. This is correct for all normal subscribers. For PBX operation, the selected lines are connected as shown for lines 92, 93, 94, 95 ie, 32, 33, 34, 35 on the B2 arc.

202. During the receipt of the tens digit and the self drive of the B selector the outlets are earthed via relay contacts as shown, and the circuit behaves as described above.

203. When the caller dials the last two digits 92, the B2 wipers drive and step to position 32.

204. Relay HS operates via earthed battery, E1 (changed over), B2 wiper. Relay HS, CD2, H1 to earth and contact HS7 prepares an alternate drive circuit for B via CD2, and H1.

205. Relay H tests the line and if the line is free it operates, causes ringing to be applied and the connection to be established. H1 opens and breaks the circuit for relay HS.

206. If the line is engaged, relay H will not operate, H1 remains make and relay HS holds in the operate condition.

207. Relay CD is re-operated after testing and the B magnet is energised via HS7, CD2, H1, CD now releases and the magnet circuit is broken, the pawl of the selector moves the wipers to position 33 (line 93).

208. Testing again takes place and if the line is engaged the same sequence of events takes place and the wipers move to position 34 (line 94).

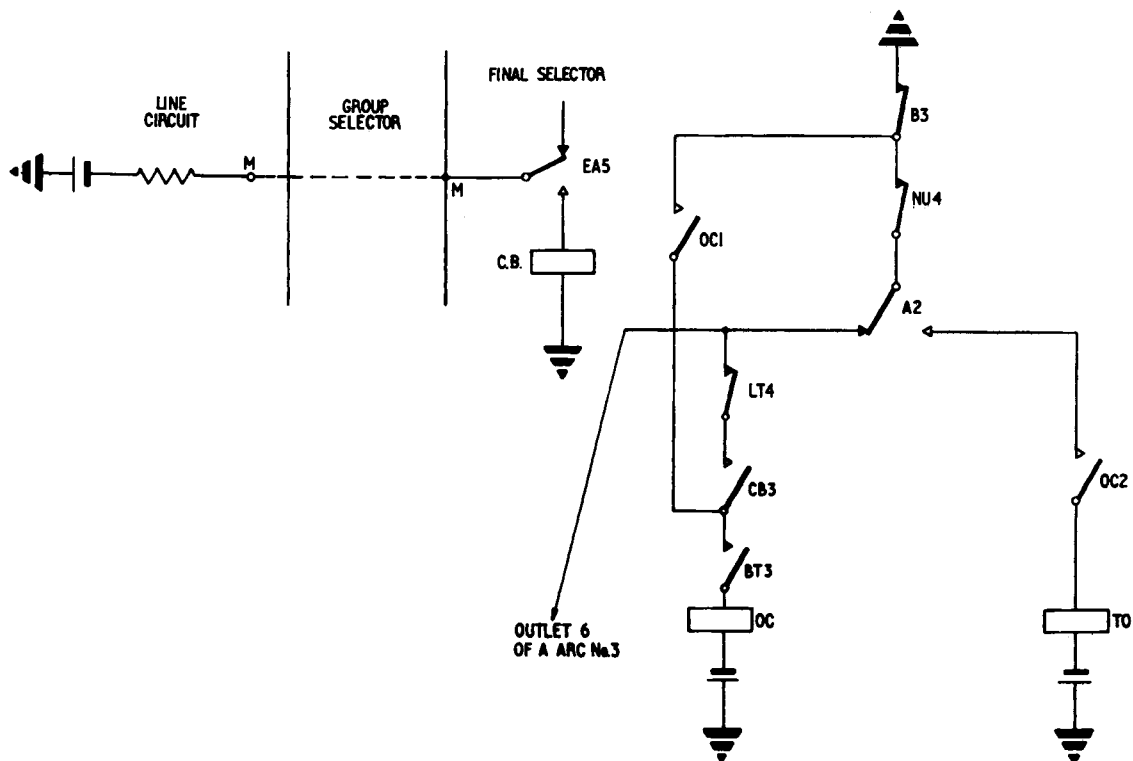
209. If 9⁴ is free, relay H will operate and H1 breaks the circuit for HS allowing it to release and the stepping circuit for magnet B is broken at HS7 and H1. Connection is now established in the normal way.

210. In the two motion type of selector, the PBX facilities are obtained by the use of the auxiliary screw arc described in para 34. h.



3181/40

Fig 40 - Preference facilities (1)



3181/41

Fig 41 - Preference facilities (2)

Preference facilities
(Fig 40)

211. Para 85 (Metering) described the use of subscribers meters and the provision of the extra arc for metering. Mention was also made of the use of the M circuit to give preference facilities. This is achieved in field exchanges by arranging different terminations of the M wire in the subscribers line circuit. Three different terminations are used as Fig 40:-

- a. When a subscriber is barred access to trunks to other exchanges, the open circuit M wire prevents the operation of various relays used in making a trunk call.
- b. A subscriber who is allowed access to trunks has an earth on his M wire, allowing the trunk access relays to operate.
- c. The subscriber with preference facilities has earthed battery connected to his M wire. This earthed battery is used to activate an additional relay in the final selector as shown in Fig 41.

212. When the caller with preference facilities makes a call, the connection is established in the normal way up to the beginning of the last impulse train when contact EA5 changes over and completes a circuit for relay CB back to the earthed battery in the subscribers line circuit.

213. Relay CB operates and CB3 prepares a circuit for relay OC. Contact LT4 is open at this stage of the dialling and relay LT does not release until testing has taken place.

214. At the end of the final impulse train the B wipers are connected to the called subscribers line and testing takes place.

215. The A2 contact is in the operate position, relay A being held by the line loop. If the line is free, connection is established in the normal manner. If engaged, relay H fails to operate, LT releases and causes the operation of BT which returns busy tone to the caller and prepares the circuit of relay OC at BT3.

216. The caller now dials an additional digit, the first break impulse releases A2 and completes the circuit for relay OC which locks and holds on OC1. When relay A re-makes, contact A2 completes the circuit for relay T0 and a contact of this relay is used to feed a special intrusion tone to the line, informing the called subscriber and the subscriber to whom he is connected that a preference subscriber is on the line.

217. Other contacts of the T0 relay are used to activate other relays which connect the speech circuit of the preference subscriber to the wanted circuit.

218. The preference subscriber is now connected to the engaged parties and requests that they clear down. When they have cleared down, ringing current is applied to the line of the wanted subscriber and the call is established from the preference subscriber.

The completed connection between subscribers
(Fig 42)

219. The calling subscriber lifts his handset, his loop operates relay L and the line finder rotates to the callers line. Relay H in the line finder operates and causes relay K in the line circuit to operate. K switches out the L relay leaving relay A in the group selector across the lines.

220. Relay A operates and in turn operates relay B which puts the guard earth on the P wire. Dial tone is returned to the caller. Relay A responds to the signals of the first impulse train and steps the selector to the required level, the selector then hunts automatically on this level until it locates a free final selector.

221. Relay H in the group selector now switches the lines through to the final selector and the 2nd A relay operates. The first A relay is now released (releasing B), and earth is applied to the P wire from the B relay in the final selector to hold all the switching relays which are in use.

222. The A relay in the final selector responds to the next two impulse trains and causes the selector to step and rotate to the required outlet. The line is checked by relay H and, if free, ringing current is applied through the F contacts and a guard earth is put on the subscribers P wire.

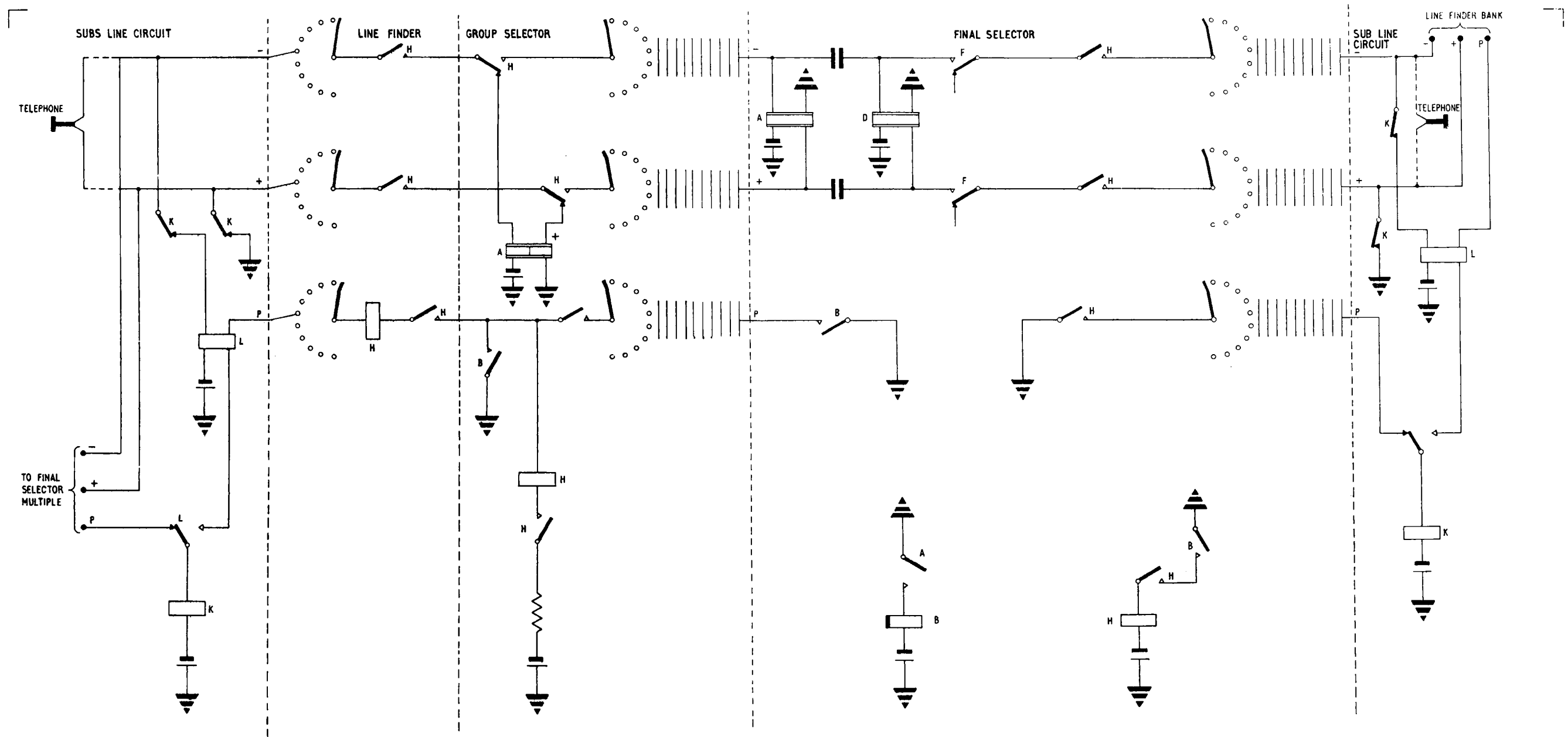
223. When the subscriber answers, the F contacts change over, disconnect the ringing and extend the connection via H contacts to the subscribers line. Relay H is held by a contact of B which is in turn controlled by A, therefore the calling subscriber controls the release of all established connections.

224. When the caller clears down, relays A and B in the final selector release and cause the release of all the switching relays. This in turn releases the selectors which now restore to normal.

Inter exchange working

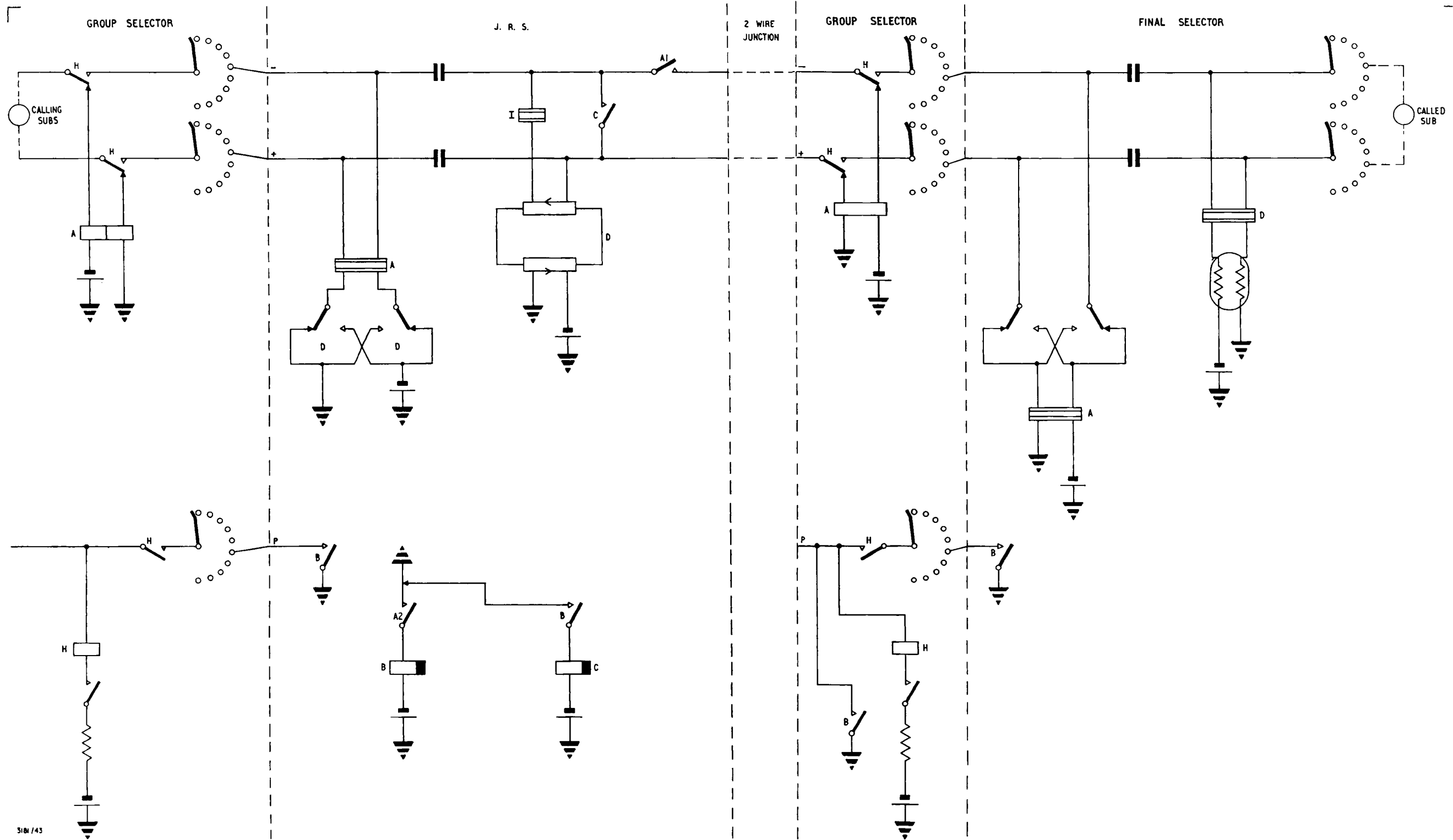
225. So far, the selection and interconnection of subscribers on the same exchange has been described, using three wires throughout the exchange, the +, -, P wires, and in some cases a fourth M wire. For connection between exchanges only two wires are used and it is therefore necessary to use additional equipment to maintain the guarding and holding, and metering or preference facilities established within the exchange.

226. Discrimination between local calls and trunk calls is usually effected at the group selector as illustrated in Fig 20.



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Fig 42 - The completed connection between subscribers



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Fig 43 - Use of junction relay set

227. As already explained, the group selector responds to the 1st digit dialled and then hunts automatically in search of a free outlet. Thus it can be arranged that the first figure dialled will determine whether the call will be routed to another local subscriber or to another exchange. In the case of the military field exchange 100/150 line, the subscribers are allocated numbers in the 600, 700 and 800 groups, and consequently levels 6, 7 and 8 of the group selectors are fed off to the appropriate final selectors. Access to the other exchanges is obtained by dialling the appropriate single digit, 0 for the manual switchboard (operator), 9 for the Commcentre exchange, 5 for the adjacent HQ exchange. The group selector responds to the digit dialled and connects to the selected exchange. Selectors in the distant exchange must now respond to impulses by the caller and connect him to the required subscriber. Thus to make a call to subscriber 623 in the adjacent exchange, the caller first dials 5, the group selector in his exchange operates and connects him, via a two wire junction to the group selectors in the adjacent exchange. These group selectors respond to the next digit, 6, and connect to the final selectors which operate to the last two digits and connect to the wanted subscriber. The transition from 3 to 2 wire working at each exchange is accomplished by the use of junction relay sets.

THE JUNCTION RELAY SET (Figs 43, 44)

General

228. The junction relay sets (JRS) used in military exchanges are of the universal (bothway) type, ie, they will operate to incoming or outgoing calls and they can also operate to manual switchboards and are required to perform the following functions:-

- a. To maintain an earth on the P wire at both exchanges and so permit the use of two wire junctions outside the exchange.
- b. To transmit dialled impulses to the selectors of the called exchange.
- c. To pass back metering conditions, busy tone, engaged tone etc.
- d. To provide operator hold conditions in the event of a call to an auto/manual switchboard.
- e. To provide transmission feed to the subscribers instruments.
- f. To detect preference subscribers and pass the appropriate signals.
- g. To deny junction access to barred subscribers.

229. Fig 43 illustrates the general principles of operation, in practise there is usually a JRS at each end of the junction line but for clarity only one is shown in the diagram.

Connection over junction circuit

230. When the calling subscriber dials a junction access number, the group selector in his own exchange hunts for and seizes a free JRS. Relay A in the JRS operates and contact A1 completes a d.c. loop via relays I and D to the distant exchange. Relay B operates through A2 and puts a guard earth on the P wire. Relay D is a low impedance shunt field relay, relay I is a high impedance relay which preserves the required high impedance across the speech path.

231. Relay A (JRS) responds to the second digit dialled and contact A1 repeats these impulses to the A relay in the distant group selector. During impulsing, relay C in the JRS is operated and one of its contacts is used to short circuit relays I and D which would otherwise cause distortion in the transmitted pulses.

232. The distant group selector responds to the 2nd digit dialled and connects to the final selector which in turn connects to the wanted subscriber when the final two digits are transmitted. A guard earth is put on the P wire at each successive stage by the final selector B contact when relay A (final selector) responds to the distant JRS.

233. When the called subscriber answers, he operates relay D in the final selector. The contacts of D cause a reversal of line current which is detected by the shunt field relay D in the JRS. This reversal is repeated to relay A (JRS) and used to effect metering in the calling subscribers circuit.

234. When the calling subscriber clears, he releases relay A in the JRS and the seized connections in the local exchange revert to normal. The A contact in the JRS breaks the junction loop and releases the A relay in the final selector. This in turn causes the release of the connections in the distant exchange.

Manual Hold

235. When a call is made to the auto/manual switchboard, it is necessary to transfer the control of the connection from the calling subscriber to the operator. This control is effected by relay I which, in this case is operated by current from the operators cord circuit. The contacts of the I relay cause the established circuit to be held even though the calling subscriber replaces his handset and releases relay A.

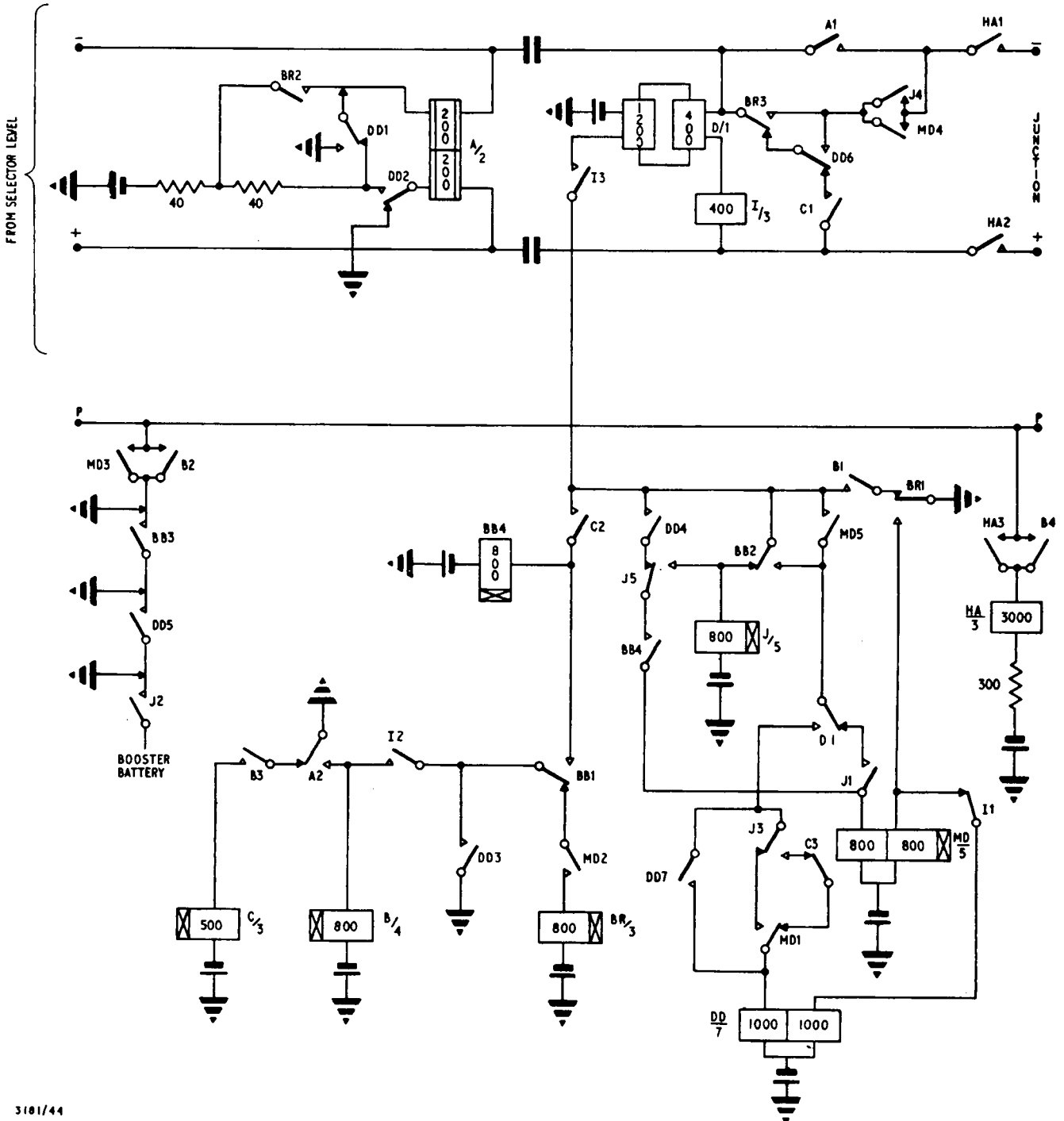
Typical JRS circuit
(Fig 44)

236. Fig 44 shows the circuit for a typical junction relay set operating between the group selector and the two wire junction to distant exchanges.

Pre-dialling 2nd digit

237. The group selector has responded to the first digit and extended the line loop to the JRS. Relay A operates, A2 operates relay B, B2 puts earth on the P wire. B4 operates HA which locks on HA3. HA1 and HA2 extend the line loop to the distant selector, the outgoing line loop consisting of HA1, A1, relay D, relay I, HA2. Relay J operates through B1 and prepares booster battery circuit, for metering, via J2. Relay I operates from the current flowing in the loop from the distant

selector; I1 disconnects one coil of relay DD and I3 polarises relay D. Relays A, B, HA, J, I, are all in the operate condition.



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Fig 44 - Circuit for junction relay set

Impulsing

238. Relay A responds to the dialled impulses. The first break signal operates relay C via A2. C1 short circuits the line coil of relay D and of relay I so providing a zero resistance impulsing loop in the relay set. C2 operates relay BB, and BB2 operates relay MD which holds through D1 and MD5. Contact A1 repeats the impulses to the distant selector. On completion of impulsing, relay C releases and removes the short circuit from relays D and I.

Metering

239. When the called subscriber answers, relay D (polarised) operates to the battery reversal on the line. D1 breaks the holding circuit of relay MD. This relay is slow to release, so guarding against possible false metering if relay D should operate to current surges on the line.

240. With MD released, relay DD operates via BR1, B1, BB2, D1, J3, C3, MD1 and locks via DD7. Contacts DD1, DD2 reverse the battery supply through relay A so giving supervisory signal to a manual cord circuit should the call have been set up by the manual operator. DD4 disconnects relay J and DD5 completes the booster battery connection to the P wire while J2 is releasing. On the release of J2, earth is again applied to the P wire.

Busy condition

241. If the wanted subscriber is engaged, busy tone and busy flash are returned from the distant final selector. If the originator of the call is a subscriber, the busy tone is passed back via the relay set transmission bridge.

242. Should the call have been originated at the auto/manual switchboard it is necessary to repeat the busy flash signal to operate the supervisory lamp in the cord circuit. The busy flash signal is given by applying battery to the lines .75 seconds on, .75 seconds off. Relay I responds to these signals and at I1 prepares a circuit for flashing relay DD:-

- a. I2 disconnects BB to prevent metering and I3 disconnects the polarising coil of relay D.
- b. BR operates through MD2 (operated) and BB1 (released) when I2 is operated.
- c. BR2 connects battery through one coil of relay A to the negative wire, BR1 releases relay J, holds MD and operates DD via I.
- d. DD2 connects battery to the positive wire through the other coil of relay A.
- e. DD3 maintains a circuit for BR each time I2 releases.
- f. BR3 retains relays D and I during the release of A1 under busy flash conditions via MD4.

243. On completion of the busy flash period, relay I operates and remains operated by the current in the line loop. I2 retains relay BR, I1 disconnects DD which releases and removes the battery from the positive wire via DD2.

Releasing

244. When the caller clears down, relay A releases and A1 breaks the loop to the distant exchange. A2 releases relay B and operates relay C during the release lag of B3. C2 operates BB during the release lag of B1 and BB4 operates MD. MD3 connects guarding earth to the P wire until the final release of B when all relays restore to normal. The relay set is thus held in the engaged condition for the release periods of relays B and MD so allowing time for the distant selectors to restore to normal.

Preference facilities

245. It will be seen from Fig 44 that connection to the junction lines is dependant upon the operation of relay HA. The operation or non operation of this relay can be controlled by the M wire termination, as described in para 85 and 211, to bar selected subscribers from using junction circuits, to allow access, or to give preference access as already described.

RINGING MACHINES

246. The ringing current is usually supplied by a motor driven generator, driven from the mains or the exchange battery. The machine carries slip rings and a series of connectors which are used to provide the following tones:-

- a. 400Hz.
- b. 133Hz.
- c. 33.3Hz.

247. The main shaft of the machine is also used to drive reduction gearing which in turn operates cams. These cams are used to operate various spring contact sets to provide:-

- a. Interrupted ringing The 17Hz a.c. is connected for .4 second, the ringing lead is earthed for .2 second, ringing current again applied for .4 second, ringing lead earthed for two seconds.
- b. Busy back Spring sets open and close for .75 second alternately.
- c. Motor start For use when the motor is not run continuously.
- d. Interrupted earth At busy speed, .75 seconds on, .75 seconds off.
- e. Flicker signal Earth and battery supplied alternately at .2 seconds intervals, used for certain timing operations, similar to interrupted earth.

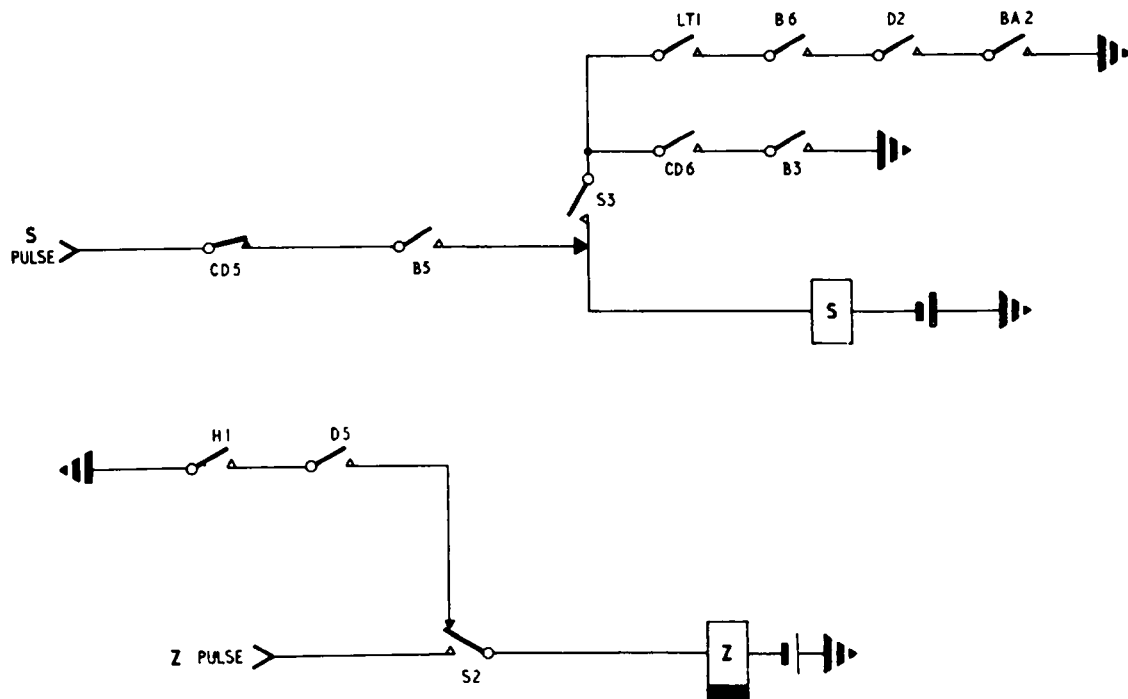
248. In the field exchanges, 25Hz ringing, 400Hz tones, are obtained from a battery driven, transistorised ringing and tone generator, with various relays providing the required interruptions.

Pulse machines

249. In addition to ringing and tone facilities there is also a requirement for various timed pulses to operate meters where necessary and to provide forced release features. In larger exchanges, these pulses are obtained from the meter pulse machine, in the field they are provided from the ring/tone generator mentioned in para 248.

Metering pulses

250. The meter pulse cycle takes three seconds, the first pulse sent out is the S pulse. This has a duration of 250 ms and prepares the meter for operation. After a delay of 550 ms the Z pulse is transmitted which has a duration of 2.1 seconds. During the period of the Z pulse, the appropriate number of meter pulses are transmitted to operate the subscribers meters.



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Fig 45 - Circuit for forced release

Forced release
(Fig 45)

251. This feature will ensure the release of equipment under the following conditions:-

- a. Faulty lines holding equipment.
- b. Subscribers fail to replace handsets.
- c. Called subscriber clears down before caller.
- d. If barred subscribers attempt to use junction facilities.
- e. If a subscriber delays too long in dialling, or if there is too long a delay between impulse trains.

252. The forced release is brought about by the application of the S pulse, followed by the Z pulse after a suitable time delay. In the case of field exchanges the delay time is 18 seconds for local calls and 108 seconds for junction calls. The pulses are used to activate or release relays and so cause the release of the switching apparatus in use.

253. Fig 45 illustrates the use of the S and Z forced release pulses in the final selector of the 100/150 field exchange. The S pulse operates relay S via CD5 (released except during impulsing), B5 (operated) and relay S holds via S3, CD6 and B3 when the S pulse is finished, or alternatively holds via LT1, B6, D2, BA2 when all these relays are operated ie, abnormal conditions.

254. After the appropriate time delay the Z pulse is applied and this operates the Z relay through contact S2, assuming the S relay is still operated. The contacts of the Z relay are used to bring about the release of all switches in use. In the event of a called subscriber clearing down, relay D is released and contact D5 operates relay Z from earth at H1.

EME/8/3181/Tels

END