June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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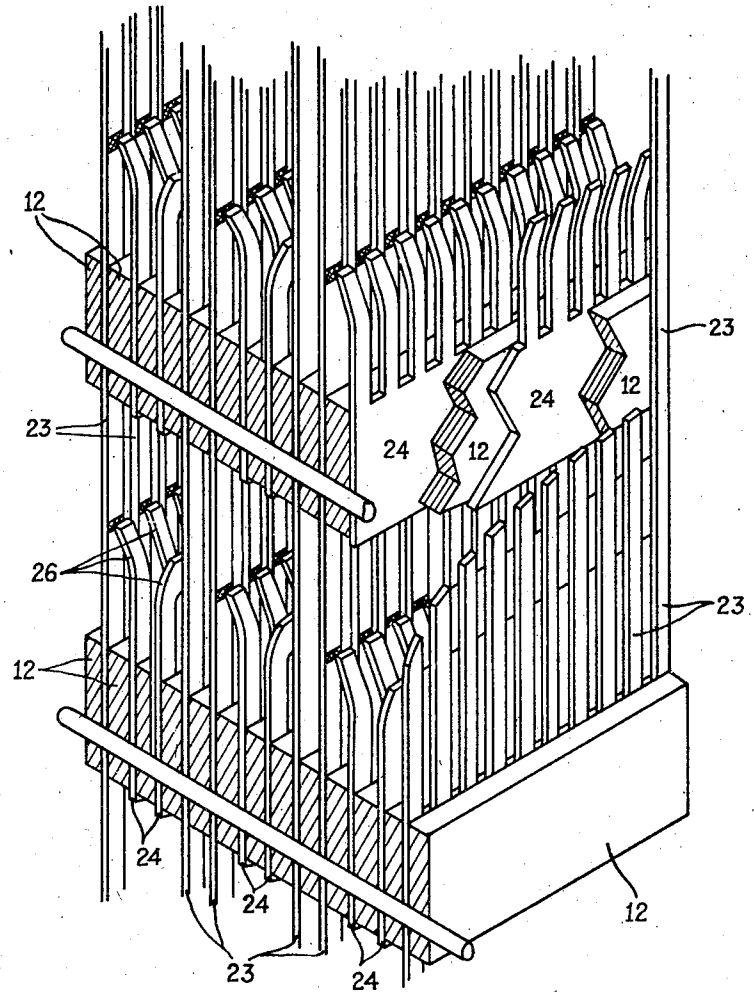

Fig. 1

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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Fig. 2

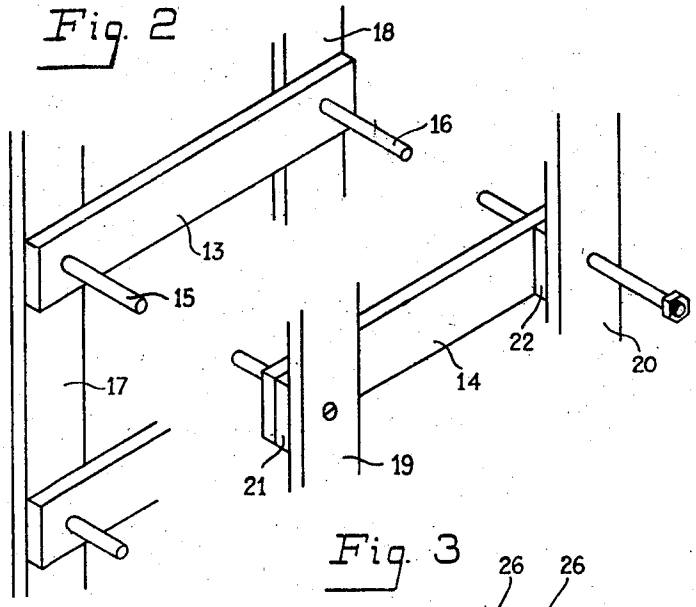


Fig. 3

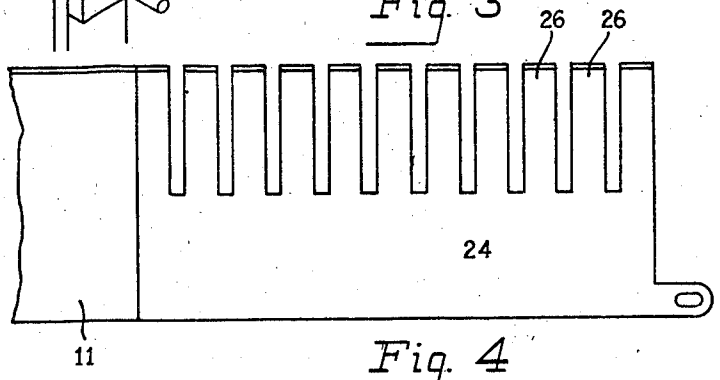
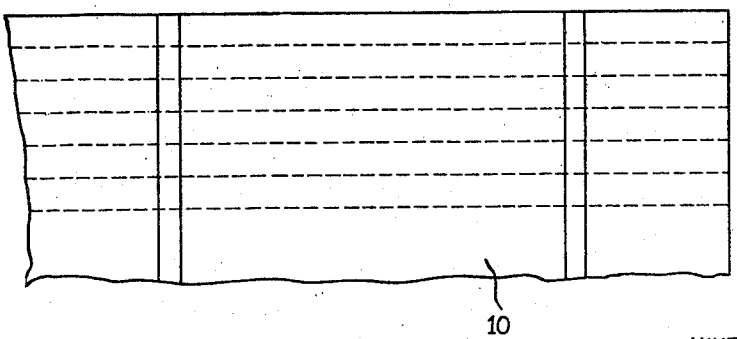


Fig. 4



INVENTOR
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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

Filed March 6, 1943 15 Sheets-Sheet 3

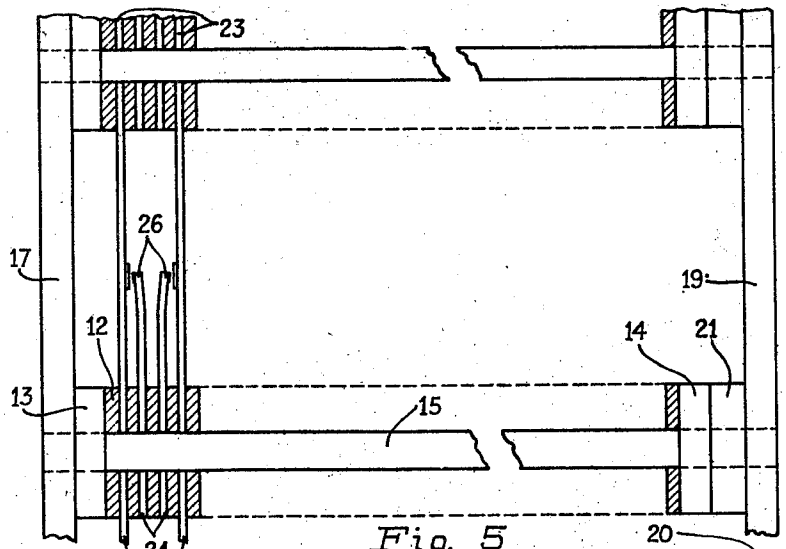

Fig. 5

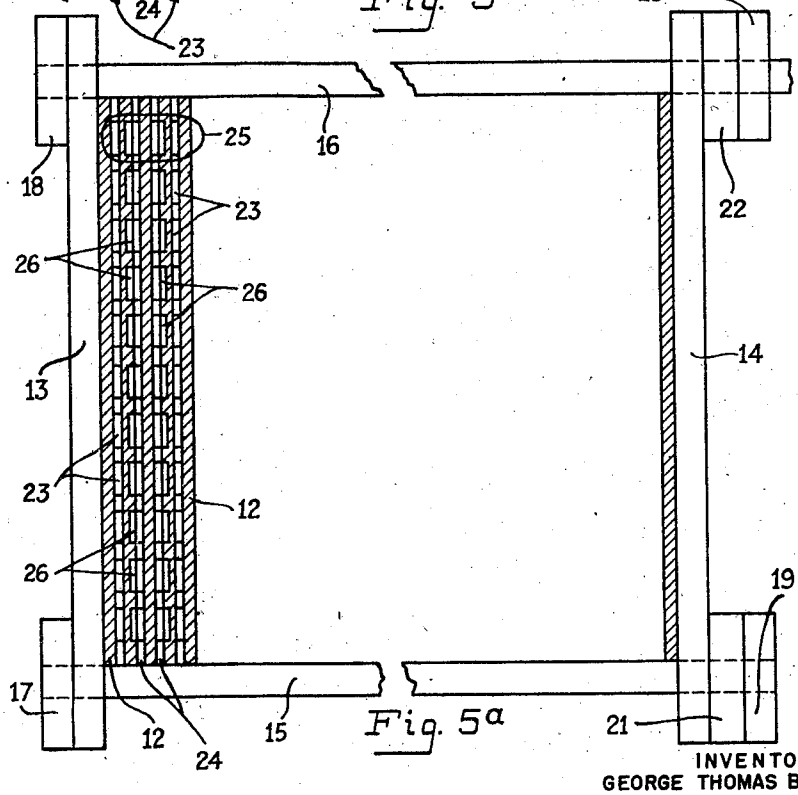

Fig. 5a

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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Fig. 7

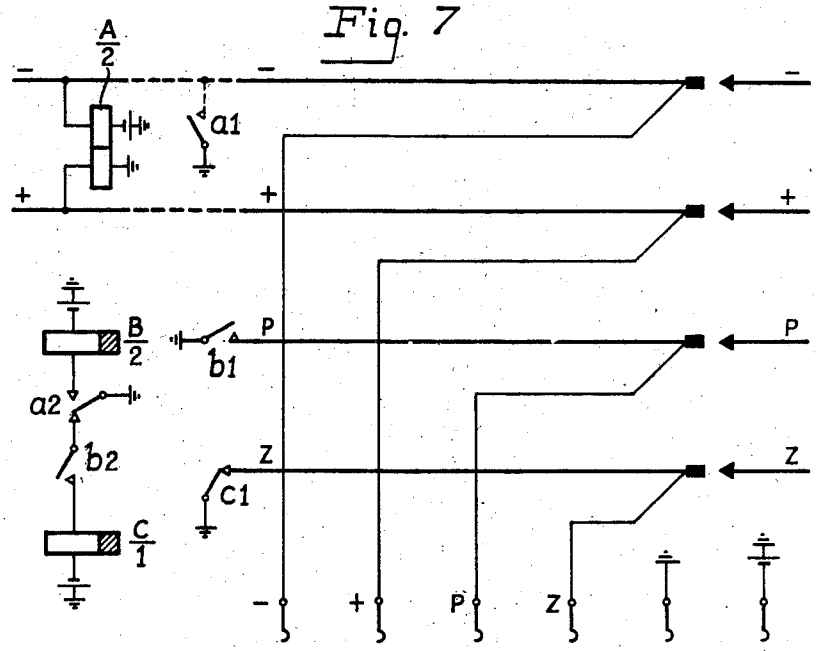
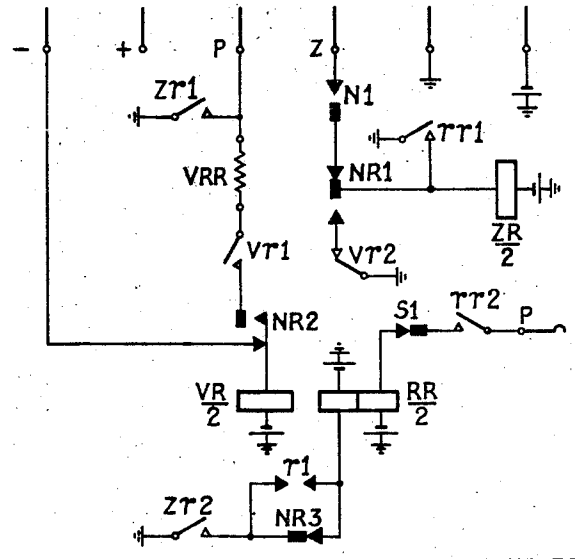


Fig. 6



INVENTOR
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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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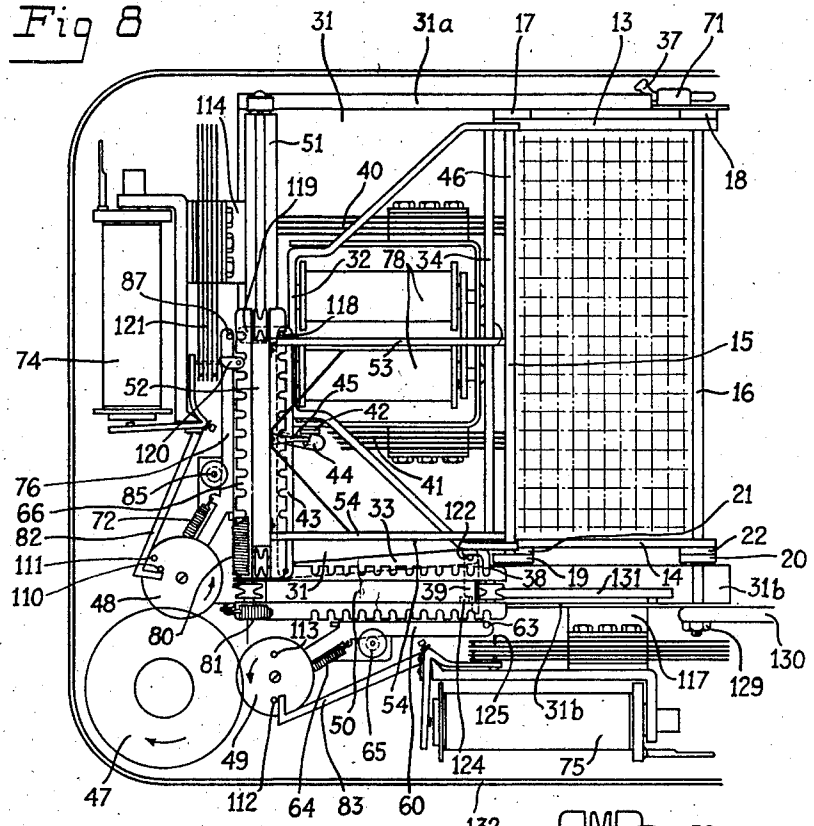
Fig 8



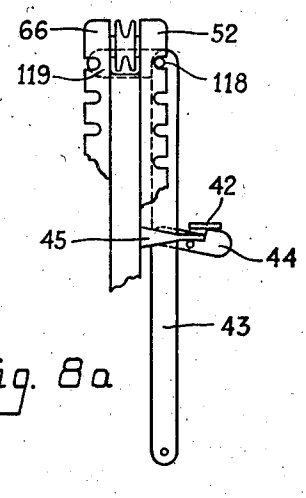


Fig. 8a

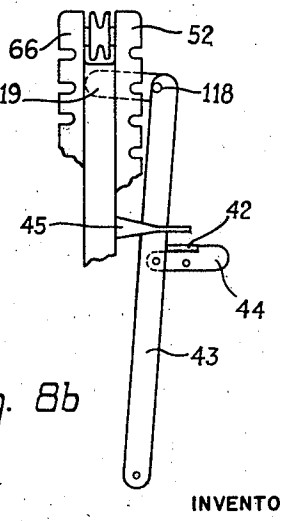


Fig. 8b

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June 18, 1946. G. T. BAKER 2,402,232

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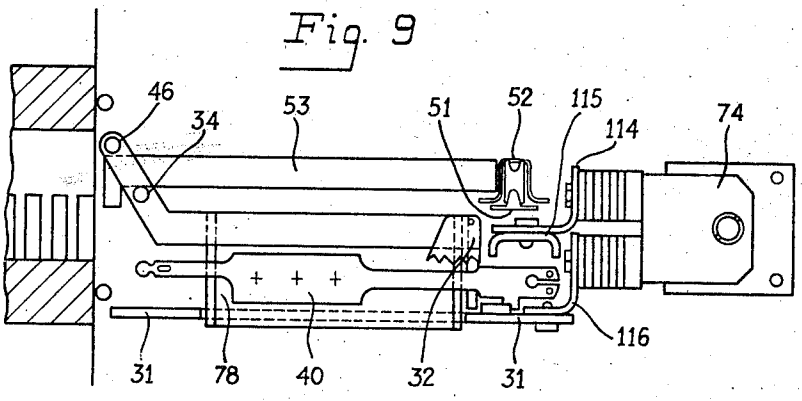
Fig. 9



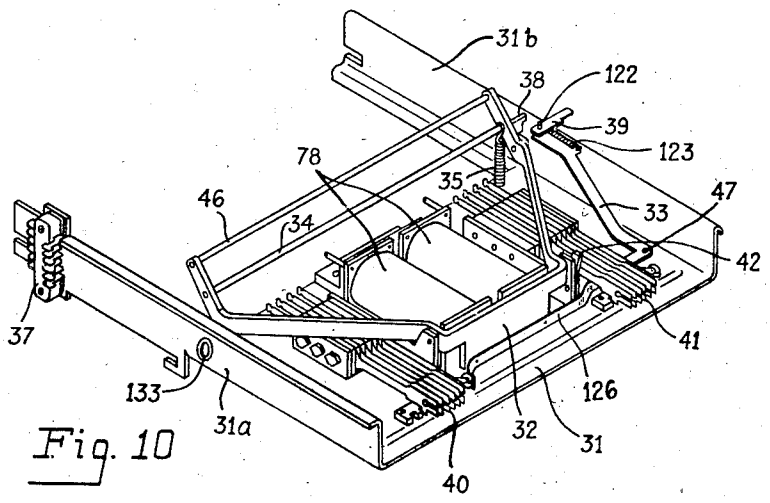


Fig. 10

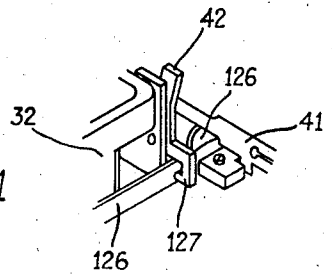


Fig. 11

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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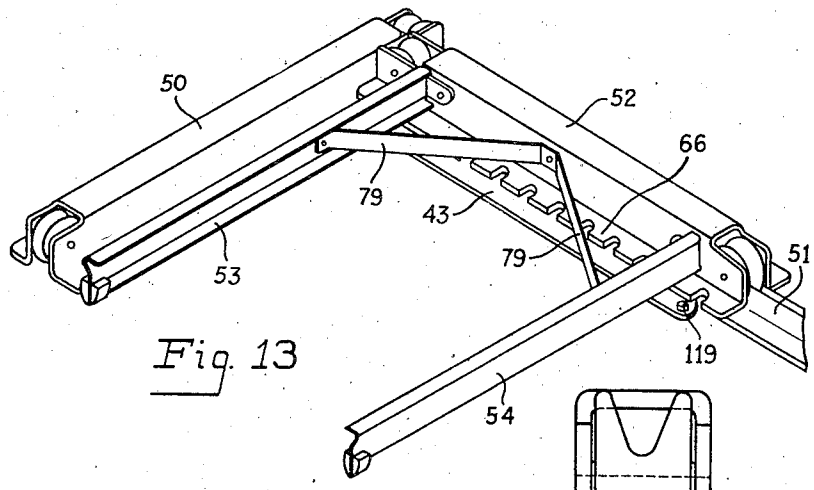
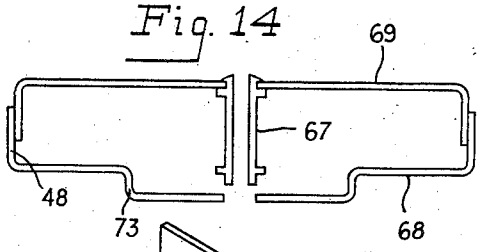


Fig. 13

Fig. 14



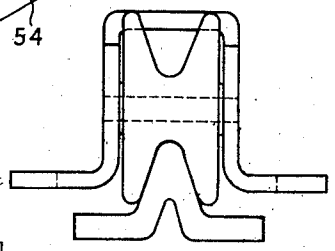


Fig. 12

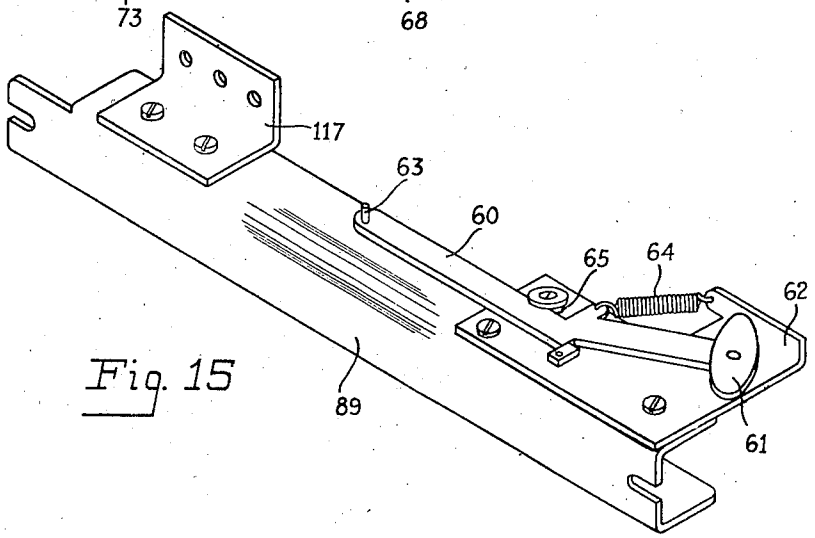


Fig. 15

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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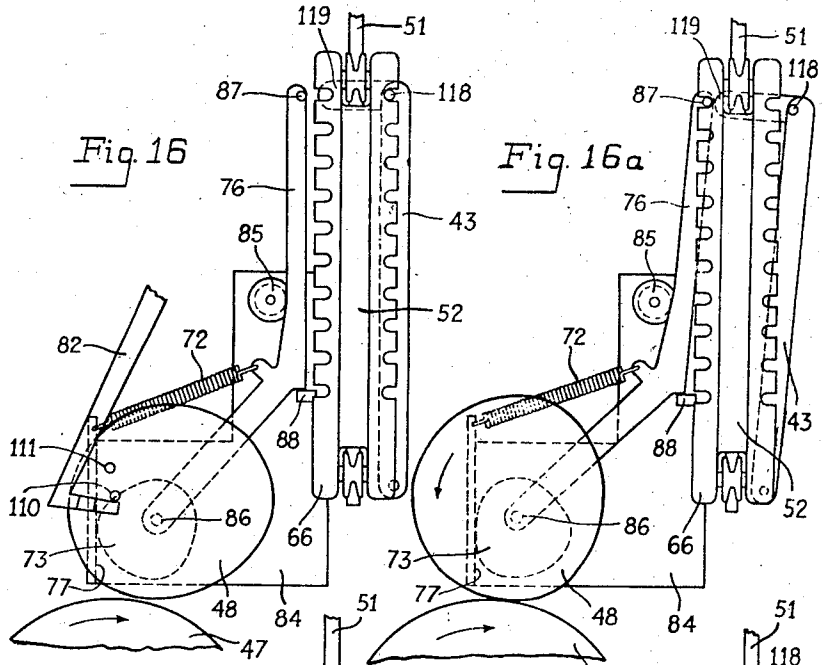

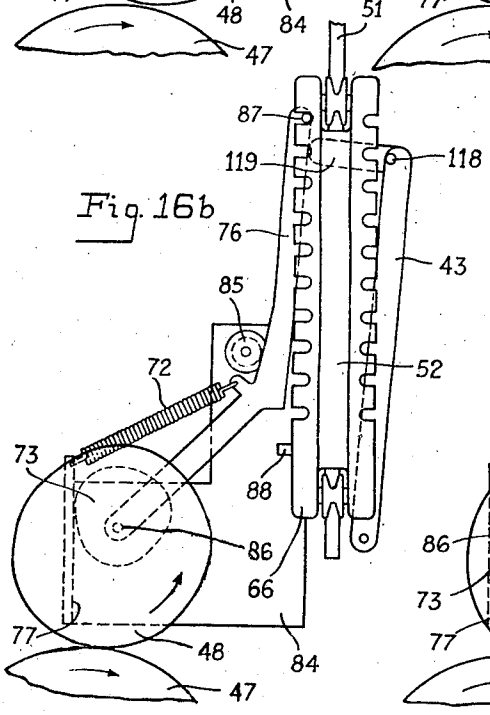

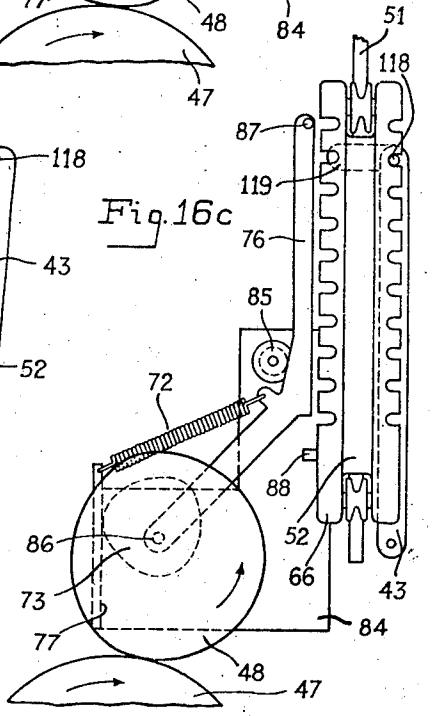

INVENTOR
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BY Chas. Th. Cauby.

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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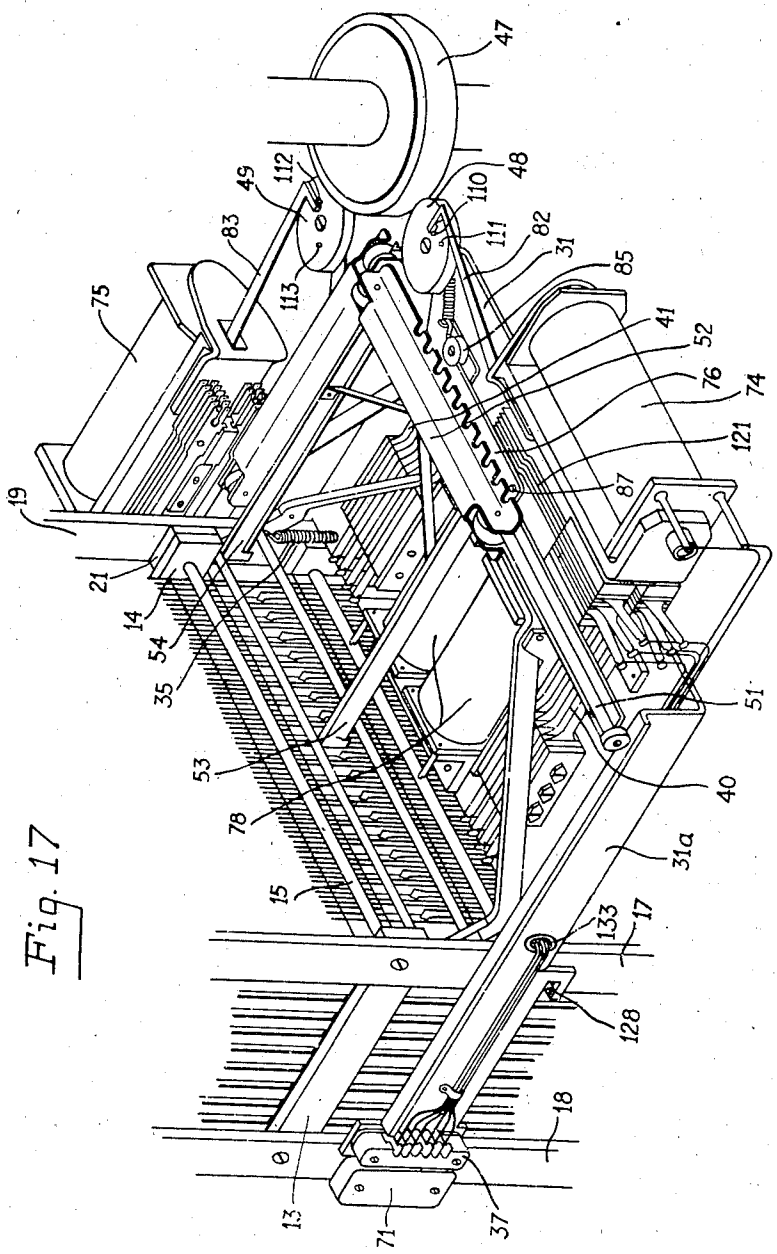

Fig. 17

INVENTOR
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June 18, 1946. G. T. BAKER 2,402,232

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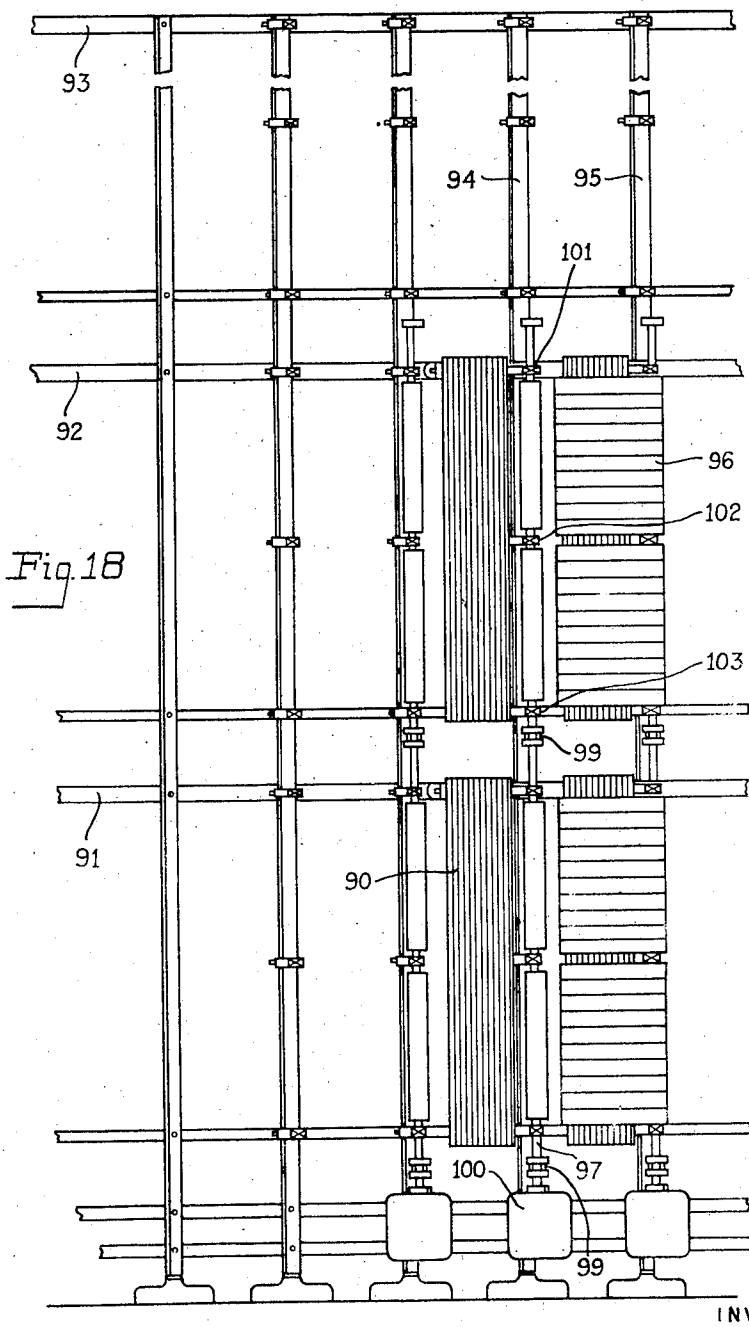

Fig. 18

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AUTOMATIC TELEPHONE SYSTEM

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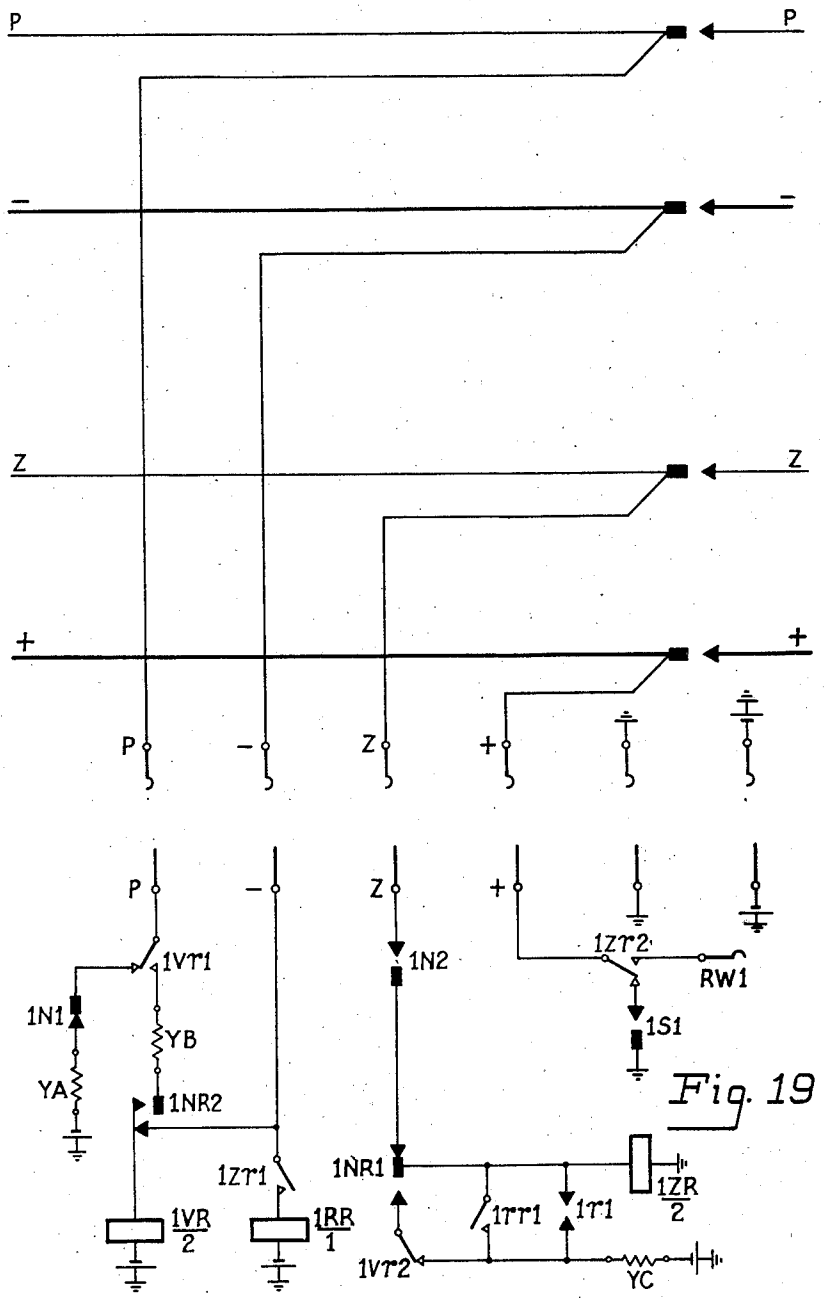

Fig. 19

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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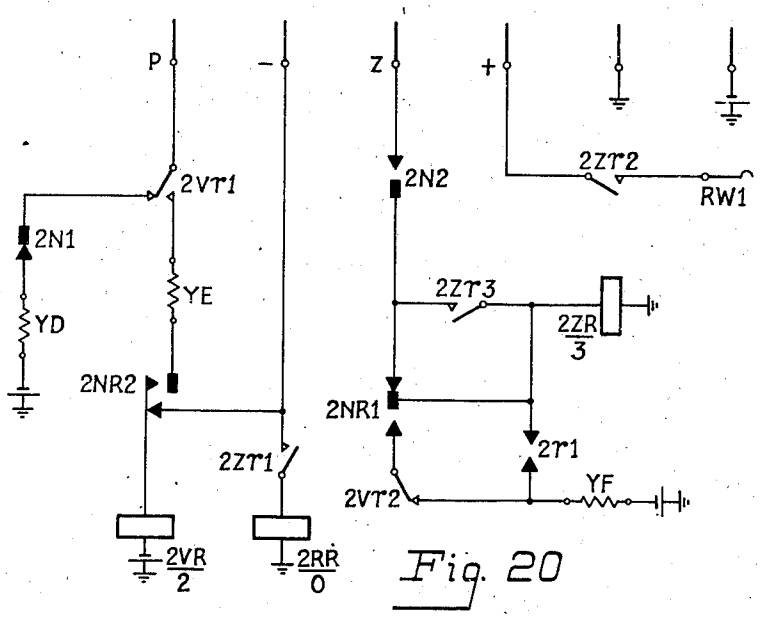

Fig. 20

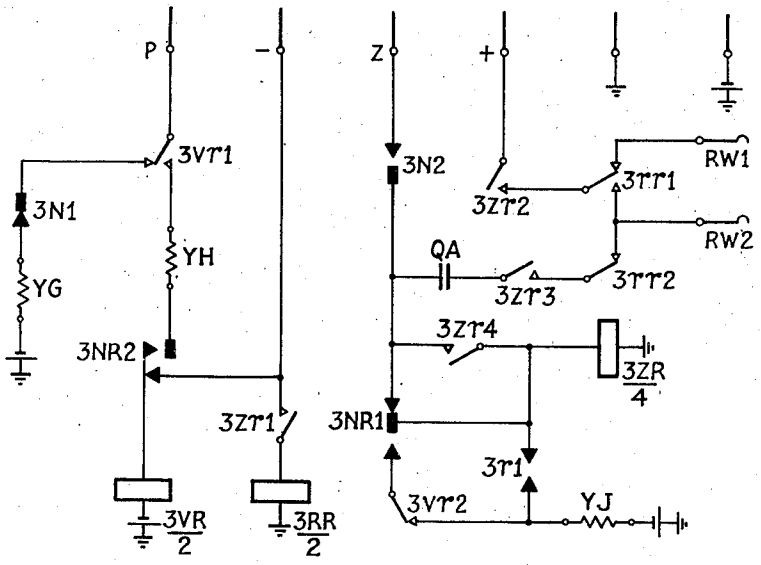

Fig. 21

INVENTOR
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BY Chas. Th. Candy

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June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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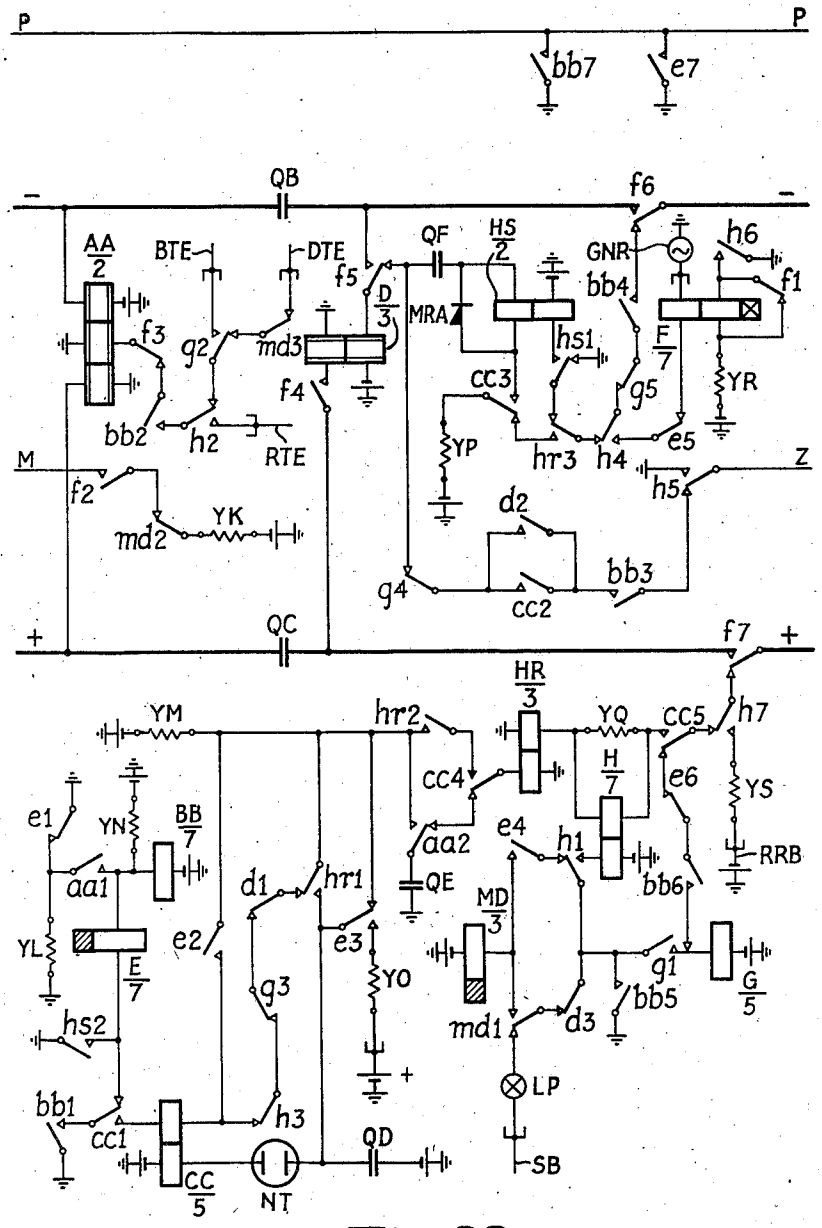

Fig. 22

INVENTOR
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June 18, 1946. G. T. BAKER 2,402,232

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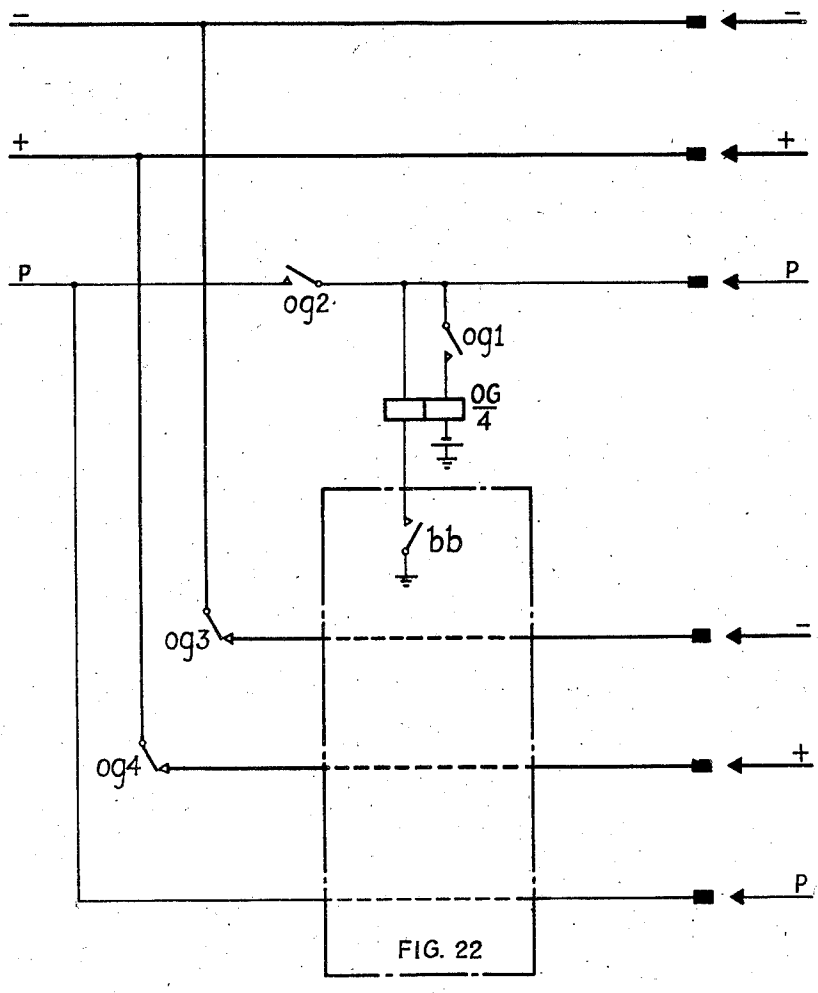

FIG. 22

Fig. 23

INVENTOR
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BY

ATTORNEY

June 18, 1946. G. T. BAKER 2,402,232

AUTOMATIC TELEPHONE SYSTEM

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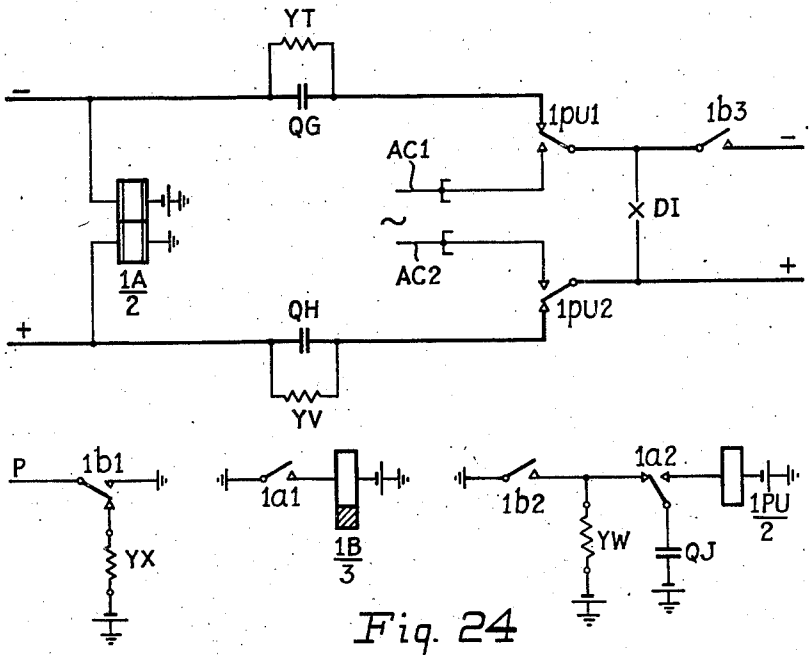

Fig. 24

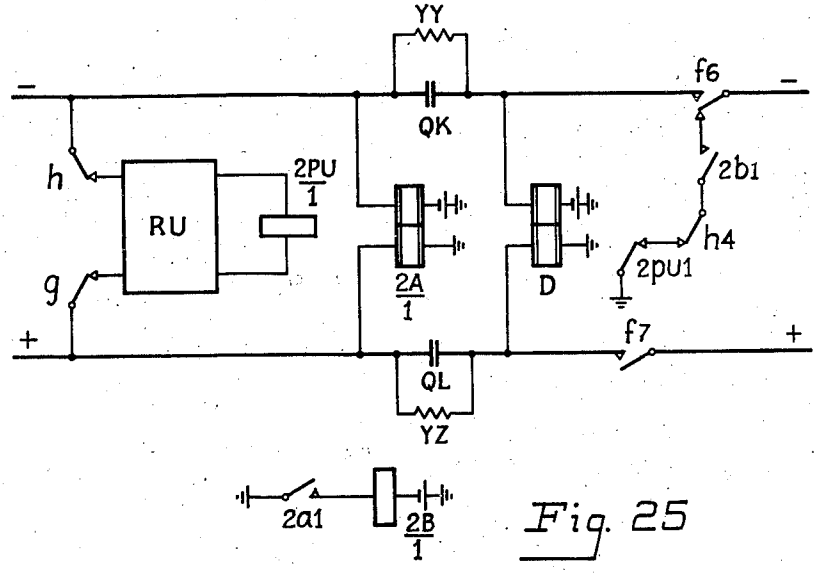

Fig. 25

INVENTOR
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BY Chas. Th. Candy
ATTORNEY

Patented June 18, 1946 2,402,232

UNITED STATES PATENT OFFICE

2,402,232

AUTOMATIC TELEPHONE SYSTEM

George Thomas Baker, Liverpool, England, assignor, by mesne assignments, to Automatic Electric Laboratories, Inc., Chicago, Ill., a corporation of Delaware

Application March 6, 1943, Serial No. 478,245
In Great Britain April 20, 1942

32 Claims. (Cl. 179—22)

1

The present invention relates to telephone systems and switching apparatus and circuits for use therewith and has for its general object the provision of a new and improved automatic telephone system in which the mechanical efficiency of power drive systems, the contact efficiency of relay and crossbar systems and the simplicity and directness of decimal step-by-step systems have been combined to good advantage.

According to one feature of the present invention a telephone system is provided in which contact-operating members having control circuits individual thereto are driven smoothly in steps of predetermined size by a continuously operating source of mechanical power to select contact members and to cause selected contact members to engage to complete a conversational circuit free of jack, wiper or like base metal contacts. Base metal contacts are the frequent cause of microphonic noises being created in the speech circuit while the smooth running ensures the minimum of external disturbance to the contacts on which the connection depends.

According to another feature of the invention a telephone system is provided in which the incoming and outgoing leads of groups of switches are connected to co-operating contact members mounted in banks, the incoming leads of each switch being also connected to jack-in points by which contact-operating members together with controlling magnets and coupling means are adapted to be readily removed and replaced as detachable units; when in position the individual control circuits of the contact-operating members are connected via the jack-in points to the incoming leads of the switch while at the same time the coupling means are correctly aligned with respect to a rotary shaft extending along the bank. Such an arrangement enables a conversational circuit to be completed independent of a connection through the jack-in points while avoiding the necessity of using complicated common control circuits.

According to another feature of the present invention a telephone system is provided in which the speaking circuit includes a battery feed control relay set and conversational leads involving only a single pair of co-operating precious metal contacts in each lead for each of a train of switches the selection and operation of the contacts being effected by a contact-operating member whose movement is controlled by interaction between the control relay set and the individual control circuits of each switch over the leads incoming to said switch. This enables the individual control circuits of each contact-operating member and therefore of each switch to be simplified while at the same time it ensures a conversational circuit with the minimum number of contacts and therefore with the minimum number of parts which are liable to give rise to microphonic noises due to external disturbances.

2

According to a further feature of the present invention a telephone system is provided having banks of co-operating contact members for connecting individual sets of incoming leads of a group of switches to selected outgoing leads common to the group whereby a conversational circuit can be completed over precious metal contacts and the selection of the co-operating contact members which are to engage can be effected by contact-operating members which move smoothly in a step-by-step manner under control exerted over the incoming leads.

According to a further feature of the invention in a telephone system rows of conductors extend parallel to each other and cross while being normally insulated from other rows of conductors extending at right angles thereto, the said conductors having contacting points at their points of intersection; contact-operating members being controlled from a source of continuously acting mechanical power so as to move smoothly to cause conductors in one row to engage with conductors in other rows at selected points of intersection.

According to a further feature of the invention in a telephone system rows of conductors are arranged to extend parallel to each other and cross while being normally insulated from other rows of conductors extending at right angles thereto, said conductors having contacting points at their points of intersection, contact-operating members being controlled in a step-by-step manner to move smoothly to cause conductors in one row to engage with conductors in other rows at selected points of intersection.

According to a further feature of the invention a telephone system is provided having a contact bank consisting of conductors extending in parallel rows and having contacting points in a series of rows in parallel planes and further conductors individual to each row in each plane extending at right angles to the first conductors and each having contacting points for each conductor in the row, corresponding contacting points of the said conductors being in juxtaposition but normally out of engagement, a contact-operating member being provided for each of said planes of contacting points which is adapted to be moved across the ends of said rows to select

one of said further conductors and to move parallel to the selected conductor to engage the corresponding contacting point of a selected one of said first mentioned conductors.

A further feature of the new telephone system is especially concerned with extending the range of impulses which will effectively control the mechanisms and the setting up of a connection. It will be appreciated that in existing systems not only have the original impulse senders at subscribers' premises and in other situations to generate impulses within predetermined limits, but also the impulses once generated are subject to distortion dependent upon the line conditions and also upon the number of times they are repeated and it is a further feature of the present invention that a telephone system is provided in which the impulse-responding mechanisms and the impulse repeaters are especially adapted to respond to a predetermined change of current in an impulse, the impulse-responding mechanisms being adapted to effect a complete operation mechanically independent of the mechanism which initiates such an operation and the impulse repeaters to generate a complete impulse independent of the device which causes the impulse to be generated.

The invention will be better understood by referring to the accompanying drawings which illustrate a telephone system by way of example embodying the features referred to above.

Referring now to the drawings,

Fig. 1 shows a perspective part view of a rectilinear continuous bank showing the metal strip multiples and the precious metal contacts, a desired connection being effected by the appropriate operation of cordless contact-operating members, conveniently referred to hereinafter as "wiper arms."

Fig. 2 shows a perspective part view of the clamping and supporting arrangements for the rectilinear continuous bank of Fig. 1.

Fig. 3 shows a plan view of a precious metal contacted comb plate as it is being stamped from a metal sheet which is edged with precious metal, while Fig. 4 shows how the continuous metal strip multiples are stamped from a suitable metal sheet on which precious metal contact strips have been rolled.

Fig. 5 shows a part elevational view of the rectilinear continuous bank and showing in detail an end view of part of a level, while Fig. 5*a* shows a corresponding plan view.

Figs. 6 and 7 together show the circuit of a ten-level ten-outlet per level group selector and the basic control circuit therefor.

Fig. 8 shows a reduced diagrammatic plan view of a cam driven two-stage selector and also the position occupied by the bank with respect thereto. Fig. 8*a* shows a plan view of the primary carriage release control mechanism with the carriage in its normal position, while Fig. 8*b* is a similar view of the conditions obtaining when the switch has completed the secondary release movement from the position to which it has been previously set and is about to commence its primary release movement.

Fig. 9 shows a part diagrammatic side elevational view of the two-stage selector and its associated bank and approximates its full size.

Fig. 10 shows a reduced perspective view of the selector chassis with the selector components assembled thereon.

Fig. 11 shows the slight mechanical modifications which are involved in meeting special release action requirements.

Fig. 12 shows an enlarged end view of one end of one leg of a carriage shown on its running rail, while Fig. 13 shows an enlarged perspective view of the primary and secondary carriages together with the wiper arms.

Fig. 14 shows an enlarged sectional view of the primary drive main and subsidiary cams, which, as shown, are integral with one another, while Fig. 15 shows an enlarged perspective view of the selector secondary drive arrangements from which, for the sake of clarity, the main drive cam is assumed to have been removed. The four basic stages of operation involved in driving the selector primary carriage one step is shown in the four figures 16 to 16*c* inclusive.

Fig. 17 shows a reduced perspective view of the complete selector jacked in position adjacent the bank.

Fig. 18 shows a front elevation of exchange mounting uprights, one of which is equipped with two twenty-selector bank multiples and associated selectors, another with two twenty-selector bank multiples only, while the remainder are shown in various stages of assembly.

Fig. 19 shows circuits of a 10/10 battery testing group selector.

Fig. 20 shows circuits of a 10/10 regular final selector and Fig. 21 shows circuits of a 2–10 line P. B. X 10/10 final selector.

Fig. 22 shows circuits of the control relay set for a train of group selector and final selector switches.

Fig. 23 shows circuits of the switching arrangements for outgoing selector levels.

Fig. 24 shows basic circuits of a D. C./A. C. outgoing impulse repeater for inter-exchange working, while, Fig. 25 shows similar circuits of a relay set for terminating the incoming end of inter-exchange junctions.

As so much of the new telephone system according to the present invention is concerned with a special form of contact bank, a description will first be given of the construction of a preferred form of bank according to the invention.

A bank is formed by continuous strips **23** running the full length of the predetermined multiple and as shown in the part view of Fig. 1 and in Figs. 5 and 5*a* these are clamped at opposite sides of selectors to form fixed contact members the intervening space between the clampings forming the bank contacts for one selector. At the end of the multiple it will be understood that the strips **23** are fanned out to form wiring tags. That part of the bank multiple allocated per selector will subsequently be referred to as a selector bank so that Fig. 1 may be described as showing a part view of two selector banks in each of which are included three levels of two conductors each. A level of one bank is moreover assumed to have been broken away in order more closely to illustrate its construction. Each bank will be preferably of the 100 point type, that is to say, with ten levels of ten sets of contacts, each set of four contacts being formed on four strips and four combs **24**; on each level there will be provided in addition the usual eleventh step set of contacts **25** for overflow busy indication purposes.

A multiple will usually comprise twenty such banks assembled together one above the other, the necessary multipling being inherently performed by virtue of the use of continuous strips **23** which connect with the outgoing trunks. The

connecting function of the ordinary selector wipers and cords is taken by a set of comb plates **24** one of which is provided for each row of strips, conveniently referred to as a level, of each bank and having fingers **26** aligned with the various bank strips. Each finger of a comb plate such as **24** forms a movable contact member. All bank contacts are made of precious metal such as silver, and to make this a commercial proposition all the silver/base metal junctions are made by rolling, this rolling operation being carried out in the stock before blanking.

The continuous strips are stamped from a metal sheet such as **10** (Fig. 4) the width of which sheet equals the length of strip required. On this sheet silver contact strips will have been previously rolled at right angles to the direction of the trunk strips (as shown) and at spacings of say 1½ inches, this distance representing the calculated vertical distance required between bank centres to accommodate the selector switches one above another. The comb plates are stamped from springy metal ribbon **11** (Fig. 3) of suitable width and provided with a rolled silver edge of, say, about 20 mils width. The comb plate fingers are preferably each split with a saw cut (not shown) to give a twin contact effect and the plates are subsequently formed to give the requisite shape shown in Figs. 1 and 5.

Each row of contact members in a bank is separated from its neighbour by an insulating plate such as **12** (Figs. 5 and 5*a*) of a length equal to that of the comb plates and of a thickness of say 50 mils to reduce possible cross talk to a minimum and at the same time to give ample room in the level for the insertion of the wiper arms. Since each trunk strip will be clamped in each of the twenty banks through which they pass, it is not considered necessary to provide clamping bars which extend through the banks, and accordingly it will be seen that each bank of the multiple after assembly in a suitable jig will be clamped together by two horizontal clamp plates **13** and **14** (Figs. 2, 5 and 5*a*) which are secured against the bank by clamp rods **15** and **16**. The requisite spacing of 1½ inches between adjacent banks is secured by means of the four vertical members **17**, **18**, **19** and **20** which extend over the length of the multiple and which are secured at each bank by the two clamp rods provided individual thereto.

As will be described later each selector switch mechanism is adapted to jack into position against its bank in the manner shown in Fig. 17, with its wiper arms normally at rest at a distance equal to one level before the first level of the bank. To meet this requirement suitable packing pieces **21** and **22** (Fig. 8) are interposed between vertical bars **19** and **20** and the adjacent clamp bar **14**. From Fig. 8 it will be seen that the clamp rod **15** will be nearest to the selector switch mechanism and this will be of such a length as to finish off level with the vertical members **17** and **19** including its fixing nuts, or alternatively countersunk fixing screws may be used as in Fig. 17. The other clamp rod **16** will be of such a length as to extend for about ¾ of an inch at one end in order to provide suitable support for the bank multiple on the mounting upright.

Owing to the fact that the new selector requires considerably less space than existing ones the cabling should receive special consideration. Cabling will conveniently be carried at three levels, say 4′ 0″; 7′ 3″; 10′ 6″ from the floor,

by runways **91**, **92** and **93** respectively. The heights correspond to the top of the three 20 point vertical bank multiples such as 90, and accordingly the wiring from the multiple tags can drop straight into the runway. The incoming wires either rise to the runway above or drop to the one below dependent on their final destination. Thus most of the exchange wiring is already terminating virtually in a runway and the remainder reaches it by a very direct route.

It should be noted that each upright will accommodate sixty selectors, such as **96**. Assuming that the selectors are constructed as previously described with a common driving shaft for a group of switches, then the uprights such as **94** and **95** may also serve to carry and align the main driving shafts such as **97**.

The main driving shaft **97** is divided up into three sections, one per multiple (it being assumed that the top section has not been fitted). The sections are connected by a flexible coupling such as **99**, the bottom one connecting direct with the motor **100**. Each section has three bearings such as **101**, **102** and **103** bolted on to extension arms on the upright, the upper one also containing a thrust bearing to take the weight of the shaft. The extension arms carry the bearings on the side away from the selector, the other side being a flush fit against and supporting the vertical members of the bank. The projecting end of all the rear bank clamp rods are bolted into the angle-iron upright. The position of the nut on each clamp rod determines the relation between the multiple and the shafting and accordingly as each rod is bolted up a gauge corresponding to the selector will be slid into the selector mounting and the nuts adjusted to give the correct clearance.

It will be seen that the methods adopted allow a very flexible method of extending or equipping an exchange. Suppose only one multiple is required on an upright. The angle iron serves the three multiples on the same upright. All the other items however are put in for one multiple only, i. e. the extension arms, bearings, shaft and bank. Should another multiple be required, the bearing shaft and bank, etc., can be added without disturbing the existing equipment. This makes it possible to fill up the uprights completely without leaving spare multiples.

The actual arrangement of selectors on the various uprights is such as to give the minimum cabling. Two methods are possible, one, in which all the first selectors occupy certain uprights, second selectors other, and final selectors still more. The second method is that in which first selectors occupy the top multiple on all uprights, second selectors the centre one and final selectors the bottom or vice versa. The second arrangement by spreading a single rank of selectors over a number of shafts, makes the effect of a drive failure of one shaft less important.

In the event of a single motor failure, sprockets of the bicycle type may be fitted on the shaft having the faulty drive and on an adjacent one and connected by a length of bicycle chain allowing one motor to take the dual load while repairs were being effected.

If motors are provided common to an upright from an exchange maintenance point of view a further improvement might be incorporated in the switch construction which would further enhance its value. Briefly, the switch cover could form an integral part of the switch and within which a short individual roller drive would be

located. To this drive would be coupled a pinion which would slightly project from the switch in such manner as to engage with a corresponding pinion on a common motor driven driving shaft when the switch is jacked into position. The short roller drive within each switch would thus be in continuous rotation so long as the switch is jacked in position and would be coupled up by the friction driving cams in the same manner as coupling is effected with the common driving roller. The advantage obtained is that each switch could be a sealed unit which would be sold to a customer as such, and which, if anything went wrong, would be returned to the manufacturer for repair or re-adjustment where the best possible arrangements for adjustment and/or repair would be available. This feature would have particular appeal in the case of private automatic exchanges where skilled maintenance personnel and suitable maintenance equipment are not ordinarily readily available. The sealed cover arrangements would furthermore provide an effective remedy against unnecessary wear and trouble which results from the ingress of dust and abrasives which is always likely to occur when maintenance and equipment is performed on site, as is usual at present.

The switch mechanism which controls the movement of the wiper or contact-operating arms has two movements, one across the contact bank and the other into the contact bank. These movements will be referred to as primary and secondary movements respectively. A description of the switching construction will now be given with particular reference to Fig. 8.

With regard to Fig. 8 it should be explained that it is partly diagrammatic and not in exact accordance with the exact construction. For instance, the driving cams are shown circular with a central pivot and overlapping the continuously operating roller, whereas the primary cam should be of the shape shown in Fig. 16 and should be pivoted eccentrically as shown. The secondary driving cam which is adapted to advance the secondary carriage through two steps per revolution is of the same size as the primary cam, but the shape of both this secondary cam and its subsidiary cam are modified accordingly, the shape of the subsidiary cam being on the lines indicated in the perspective view of Fig. 15.

A further point by which the selector shown in Fig. 8 differs from actual practice is that the primary cam is shown to be of the two-stage escapement release type while the secondary cam is shown to be of the single stage simple release type so that the former is only released and allowed to engage with the driving roller when the corresponding controlling relay releases after having been operated, while the latter is released and allowed to engage with the roller as soon as the secondary control relay operates. With the simple circuit arrangements to be described the selector is therefore only suitable for functioning in a group selecting capacity when it has to respond to trains of impulses for its primary direction of movement and when it has to self-drive in the secondary direction so as to perform a hunting operation. Both primary and secondary cams may be of the simple catch release type shown in connection with the secondary cam in Fig. 8 if the circuit arrangements are suitably modified.

Referring to Fig. 8 it will be seen that the power source for the operation of the selector is derived from a hard rubber roller 47, rotating on a common shaft at a constant speed, say 10 R. P. S.

The primary and secondary driving cams 48 and 49 are each eccentric and pivoted so as to be just clear of the roller on its smallest radius. Each cam has a spring 72 or 64 associated with it which stores sufficient energy to give the cam a small rotational movement when a catch controlled by a control relay 74 or 75 is released. When a control relay has effectively released the catch the surface of the cam after a slight movement comes into contact with the roller which continues the rotation of the cam. As is later fully described, the pivot of the cam is moved away from the roller as the cam rotates, the pressure between the cam and the roller due to the load automatically preventing slipping. The pivot of the cam transmits its movement by a single member 76 or 60 to direct a carriage 50 or 52. A subsidiary cam integral with the main cam and operating upon a fixed surface causes the driving pin 87 to be moved in and out of engagement with the driving teeth thus avoiding ratchet and pawls and ensuring a constant lock of the carriage at all times. The contour of the main cam is such as to give constant acceleration and deceleration to the carriage thus reducing stresses to a minimum.

The switch is built up upon a chassis 31 on which the primary and secondary control relays 74, 75 are mounted, either directly or indirectly as will be later described. Two carriages are provided, a U-shaped primary carriage 52 (see Fig. 13), the two side arms 53 and 54 of which form the wiper arms, and an L-shaped secondary carriage 50, on the long arm 51 of which the primary carriage is adapted to run. Each of the carriages runs on rollers and is provided with a toothed driving member, the primary carriage being adapted to be moved step-by-step on a rail provided by the long arm of the secondary carriage and thus to carry with it the wiper arms 53 and 54, a state of balance therefor being maintained by the wiper arms which rest on a rail 34 positioned at right angles thereto and forming an extension of the release magnet armature 32 (see also Fig. 10). The secondary carriage is adapted to be moved step-by-step on rails provided by the chassis and thus to carry with it the primary carriage and associated wiper arms.

As an introduction to the operation of the switch it will be assumed that it is functioning as a final selector, i. e. both basic movements are controlled by dialled impulses.

In this case both primary and secondary cams will have to be of the two-stage release type or alternatively suitable circuit arrangements will have to be provided to allow of impulse control of single-stage release cams.

On receipt of the first train of impulses, the primary relay 74 responds and in a manner to be later described intermittently couples the associated driving cam 48 with the roller drive 47 with the result that a driving member 76 pivoted on the same pivot as the cam is given a reciprocating and rocking motion and its tip co-operates with the toothed driving member of the primary carriage 52 to advance it a number of steps corresponding to the number of impulses dialled and thereupon to set the wiper arms to a position opposite the required bank level. The release magnet 78 is then energised, whereupon rail 34 secured to the magnet armature 32 raises the wiper arms 53 and 54 slightly at their tips so as to cause these tips to clear the toothed combs 24 of the bank level into which they will be subsequently inserted. The banks consist of fixed contact members 23 extending from one side of the switch to the op-

posite side in the form of metallic strips and movable contact members, one for each fixed contact member in each switch which form the teeth of a comb 24, insulators 12 being provided between the comb plates and strips as illustrated in Fig. 1. The second train of received impulses is effective on the secondary relay 75 which in response thereto intermittently couples the associated driving cam 49 with the roller drive and the secondary driving member 60 is also given a reciprocating and rocking motion so as to cause the secondary carriage 50 to move a number of steps corresponding to the digit concerned and in so doing to carry with it the primary carriage and also the wiper arms mounted thereon. At the end of the second digit the wiper arm tips will be positioned over the required set of contacts in the bank and the release magnet is now de-energized to cause the tips to lower into the contact sets opposite to which they are positioned in order to make firm contact between the incoming trunk and the selected outgoing trunk.

When the switch is to be released the release magnet is again energised and it will be understood that the mechanical conditions of the primary and secondary ratchet retaining pawls are made such as to allow the carriages to restore to their normal positions under local spring tension, the wipers travelling light as during the initial setting operation of the switch, since the wipers will have again been lifted clear of the banks on the energisation of the release magnet.

In the development of the new automatic telephone system in which the selector according to the present invention forms a large part, mechanical and electrical design were both taken into consideration, and at this stage a preliminary circuit review will be introduced since some of the circuit aspects of the system had a very large influence on the final design.

It will, however, be appreciated that certain of the mechanical features are capable of being used independently of the circuit design and vice versa, the present invention aiming at showing how the two features of design may be combined with advantage.

One of the major distinctions of this selector switch is that the connecting function is now part of the bank and virtually divorced from the selector. It seems highly desirable to maintain this condition rigidly not only for selector simplification but also for talking efficiency. Hence all switching contacts must be kept out of the through wires which in every selector must look like the right-hand top portion of Fig. 7 or the top portion of Fig. 19, from which it will be seen that the speaking path at each selector passes through neither relay contacts nor jack-in plug and socket points.

In designing circuits to meet this condition the following guiding factors were taken into consideration:

1. It is extremely advisable that the holding and battery feeding bridge shall be in the first stage or at least in an early position in the train.

2. The avoidance of line contacts means that selectors provided with two or more sets of wiper arms and banks should not be provided as these switching relays so that generally there will be only one available outlet per step on any level such as on a 100 outlet (ten levels of ten outlets each) selector and it is proposed to use such a 100 outlet selector in the new system. The new selector drive arrangements may, however, enable a secondary movement search speed to be obtained, which will permit of fifteen or more outlets to be hunted over in a direct line. The use of such selectors also permits four wires to be used and this fourth wire is made use of to simplify subsequent circuit design. It also simplifies the circuit problems which arise when a feeding bridge is employed at any early stage in the switch train.

3. The use of the fourth wire opens up the possibility of avoiding the use of independent relays in the selectors. The primary and secondary magnets may be used as relays, since they can conveniently be of the same general design as the standard British post-office type relays.

4. The necessity of eliminating an extra mounting means for relays enables the selector to assume whatever shape is most suitable for its own purpose and it is found that a flat type of construction with a height only of the order of 1½ inches is quite possible.

Every selector normally contains three basic relays usually designated A, B and C. The present circuits are such that these relays need be provided only once per train thus further justifying the use of 100 outlet selectors and effecting material economies in relays.

One of the problems created by employing the battery feeding relays at an early stage in the connection is that of impulsing. In this case the relays usually subject to impulse failure are concentrated in the first stage so no difference is encountered there. The magnets are subject to an initial extra repetition due to this cause, but in any case, this is met by the elimination of a repetition in the selectors themselves where the incoming impulses are delivered direct into the magnets instead of being repeated from an A relay. In addition to this, the magnets are self-correcting and will perform a single operation on one pulse however long or short.

Figs. 6 and 7 show the fundamentals of the new circuits. The combined primary magnet and relay VR is impulsed directly over the negative line, only one step being taken for each up and down movement of the relay.

The Z wire is used for primary/secondary changeover by the operation of the combined release magnet and relay ZR. This unit is of comparatively high resistance and hence little battery drain is involved in maintaining it energised until the completion of the secondary movement. Immediately this motion commences relay VR, which also serves as the switch holding relay, is maintained from the private and on its release at the end of the call re-energises the release magnet to initiate release of the switch.

The only controls to reach the selector come over the four incoming wires. All tones and common services are supplied at the battery feeding relays. Accordingly it would appear that only battery and earth connections are required in addition to the four control wires. Hence a six point test jack has been used in place of the usual U point jack. Where selectors have to fulfil some special function this number would undoubtedly be increased but if the selector is definitely kept solely to its mechanical functions the number required is quite small.

A detailed description of these circuits will be made later after consideration has been given to the selector switch mechanism, for which reference should be had firstly to the plan layout thereof shown in Fig. 8. From this figure it will be noted that it has been possible to accommodate a two-coil release magnet 78 so that ample

power is available to meet the requirements of both the switch release and wiper arm control functions which it is adapted to perform.

In Fig. 10 is shown a view of the pressed steel selector chassis 31 with the components assembled thereon. The manufacturing operations of the chassis consist of blanking and part forming, followed by a final forming operation, the latter being limited to the completion of the side lips. Upstanding portions in the centre of the chassis may be formed integral with the chassis 31 for the purpose of supporting certain spring sets, coils, and also the release magnet armature pivots or a U shaped sub-assembly could be provided having the advantages that:

(1) The springs can be assembled on the sub-assembly before mounting on the chassis and the use of an offset screw driver is avoided.

(2) An adjustment in the vertical plane can be provided if desired.

The end slot on the plug-ended arm 31*a* of the chassis is not required if this arm is located between the separators supporting the jack on the bank vertical member and both bank clamp rods are countersunk on this side of the bank.

As regards the assembly of components on the chassis the release magnet armature 32 will first be fitted and its pivot pins will be riveted in position; the two extension arms of this armature will have been previously linked by the wiper rails 46 and 34, one of which, 34, is connected to one end of a coil spring 35 which serves as the armature return spring. The release magnet and secondary off-normal spring sets 40 and 41 respectively may then be fitted, the usual buffer blocks for which will be secured to the base of the chassis. The secondary carriage retaining pawl 38, together with its return spring (not shown), is riveted into place in such a manner that its rivet 47 serves as a pivot on which it can turn. This pawl is provided with a spring-loaded pivoted piece 39 at its head which pivots on the rotary ratchet pawl pin 122 and is used in conjunction with the rotary release as will be described later. Also attached at this stage to arm 31*a* of the chassis is the six point plug 37 which is adapted to engage with a jack secured to one of the bank vertical members when the switch is jacked into position.

Before referring to Fig. 13 which shows the primary and secondary carriages, it is desirable to point out that it was originally intended to grind and harden the lip shown on the right hand side 31*b* of the chassis in Fig. 10 but differential hardening especially of a piece this size is rather a difficult manufacturing operation and to avoid this a separate running rail of hard steel is employed say ⅛ of an inch thick by ½ an inch wide, as shown in Fig. 8 where it is designated 131, with a top contour to suit the trolleys as described later, the corresponding upright 31*b* of the chassis side being finished straight and the rail is screwed to the inside. This change assists the manufacture of the chassis since the only sharp turn has been abolished. This permits of the use of a harder quality steel with consequently greater rigidity. The other lip which contacts a flat roller required no such modification.

Referring to Fig. 13 it will be seen that the L-shaped secondary carriage comprises a short arm 50 and a long arm 51, the latter forming the running rail for the primary carriage 52 and its wiper arms 53 and 54. The rail 51 has a ridge to match the rollers, which ridge may be pressed up. Preferably if as is anticipated sufficient length of both this and the secondary running rail should be required then a special roller stock which would be cut off to the desired length would be used.

The wiper arms 53 and 54 are pressed from stiff steel of the order of 20 mils thick so as to form channel-shaped members. These arms are riveted to the member 52 and rigidity is provided by the bracing piece 79, riveted to the centre of the carriage and to the wiper arms at the point reached by the bank when the wiper is on the 11th bank contact.

Each contact operating tip is moulded on. One of the plastic resins, e. g. Bakelite, may be used for this purpose, or failing this, it may consist of two ebonite or like pieces riveted on. In either case the lower side of the wiper arm is flattened at the actual wiper tip to provide a central support.

Ordinary rubbing wipers (not shown) when required for instance for testing for a free outlet, lie along the flat part of the wiper arm on either side. They are made of any of the usual wiper materials, e. g. phosphor bronze, and are riveted to the wiper arm behind the tip. Such rivets include insulators, the inner pair of which are carried along the arm to prevent contact with the arm. The rear tags are carried to a second rivet about two inches behind the tip at which point the wiper cords are attached, thus obviating the need for the cords entering the bank.

The carriage return springs 80 and 81 lie alongside their respective carriages in each case on the outside thereof as shown in Fig. 8.

To keep the trolleys on the rails it is proposed to magnetise the latter. These are already of a hard steel and the trolleys and carriage provide an efficient return circuit. There should be no difficulty in obtaining the required retaining force.

There are components of the switch mechanism which have not yet been dealt with, or at least have only been mentioned generally, and the design and functions of the members involved will be better appreciated from the ensuing paragraphs which proceed step-by-step with the mechanical operations involved in the setting up and subsequent release of a group selector switch, i. e. with dialled primary movement and self-driven secondary movement.

Referring now to Fig. 8 the primary and secondary control relays 74 and 75 are of the British post-office standard type with extensions 82 and 83 on their respective armatures for cam control purposes. As previously mentioned, on the secondary movement these controls take the form of a simple catch that is released when the relay is energised, but for the primary movement escapement control is provided necessitating one up and one down movement to cause release. On the primary driving cam 48 the co-operating part of the escapement catch comprises the two upstanding pins 110 and 111, while on the secondary driving cam 49 the co-operating part of the simple catch is either pin 112 or pin 113 which are spaced in 180 degrees phase relationship so as to allow of a half rotation only of the cam for each release of the catch, it being appreciated that the cam is designed so as to advance the secondary carriage two steps for every revolution. As previously mentioned the control relays are supported by brackets which form the top plates of the two spring build-ups on each relay. Two brackets are thus used per relay, one

per build up, and on the primary relay the upper one 114 is supported by a channel member 115 (Fig. 9) extending across the chassis under the carriage rail 51 and the lower one 116 is secured to the floor of the chassis 31 itself. The secondary relay brackets, one of which is shown designated 117 in Fig. 8, are secured to a U section angle piece 89 shown in Fig. 15 but not in Fig. 8 and the base of which is bolted to the side of the chassis, the side arms of the angle piece each supporting a bracket.

As regards the primary and secondary drives of the switch, the principle of operation has already been described in United States application Ser. No. 413,812. The problem is essentially a dynamic one in contrast to the stationary elements which have already been discussed. Lightness of the moving parts is absolutely essential and with the construction about to be described the weight of the moving unit has been brought down to just over half an ounce.

The main improvement is that while in the construction according to the prior application two moving parts were employed one having a purely reciprocating motion, the other partaking in the reciprocating motion and having in addition a further rocking movement which causes the pawl tip to move in and out of the teeth, the construction according to the invention employs only a single piece 60 or 76 (Fig. 8) which has both reciprocating and rocking motion superimposed.

Referring to Fig. 8, the simplest drive would consist of a single strip joining the pivot of the main cam and the driving pin, but in the construction which is herein illustrated such a strip would foul the control relay armature retaining screw and the strip is bent accordingly to miss this screw. The movement is effected by the joint action of two cams, the driving cam which engages with the surface of the continuously rotating driving shaft or its equivalent and a subsidiary cam which engages with a stationary surface and while the driving cam is being rotated serves to deflect the end of the strip in a direction more or less normal to the direction of reciprocation.

The main component is the driving cam, which does the actual stepping of the selector. It is assumed that the cam moves in a straight line but in fact at each end of the stroke it is caused to move at right angles to the direction of travel under the influence of the subsidiary cam. This movement occurs when the cam contour is substantially flat and has the effect of starting to move the pin in and out of engagement while still travelling. If this is found to have any detrimental effect in practice a few degrees of flat will be allowed at the appropriate points.

The data used to design this cam was obtained as follows: The primary and secondary relays have been located as shown in Fig. 8 and if lines representing an imaginary cover 132 are drawn outside these relays, then the roller drive should fit inside this space. The continuation of the chassis line must be such that the roller must not interfere with the withdrawal of the chassis. Also the centre of the roller must be symmetrically aligned with regard to the two drives. These facts fix the roller diameter at say two inches.

If a line is drawn joining the roller centre and the driving pin when in the end tooth, the centre of the driving cam preferably lies on this line. It follows that the mean effective diameter of the cam is something over an inch, say, 1.2 inches.

The minimum period available between two successive digits is normally taken as 450 milliseconds, this being fixed by the dial switch. Of this, 150 milli-seconds is allowed for the release of the "C" of digit-train relay, leaving 300 milliseconds to perform the automatic hunting operation. Hence 30 milli-seconds is available per step giving a hunting speed of 33.3 steps per second.

The primary stepping speed must be such as to be higher than that of the fastest dial likely to be encountered. In practice dials are assumed not to exceed 14 impulses per second, and allowing a margin the vertical speed should be about 16 per second.

It will be noted that this is about half the secondary speed, and since both cams function from the same roller and are required to be about the same over-all size, it follows that the secondary cam must perform two operations per revolution and the primary, one. That is to say, the secondary cam is provided with two pins diametrically opposite and the shape of the driving cam and subsidiary cam is modified accordingly. The subsidiary cam shown in Fig. 15 is designed for the secondary movement to work with two steps per revolution. Alternatively the cams may be adjusted in size.

The revolutions per second ratio between the primary cam and roller is about 0.6 giving the latter a speed of 9.5 revs. per second. Now in automatic telephony 10 impulses per second being the basic dialling speed is most widely used. Now if the shaft speed is made 10 revs. per second it can be used to provide any machine-made impulses required and many other advantages will be obvious. Hence the roller will preferably be two inches diameter with a speed of 10 revs. per second.

The primary speed will be made exactly half the secondary, giving a stepping time of 60 milli-seconds. The usual division of an impulse in telephony is 66% for the operate stroke and the remainder for the release, and this ratio will be retained. Hence the forward primary stroke occupies 40 milli-seconds and the return, 20 milli-seconds. The secondary of course uses half these times.

In response to a train of dialled impulses the primary relay 74 responds and advances primary carriage 52 along the long arm 51 of the secondary carriage a number of steps corresponding to the digit dialled and thereupon sets the wiper arms carried by carriage 52 to a position opposite the required bank level. This is performed in the following manner.

From reference to Fig. 16 of the four operational views of the primary drive arrangement, Figs. 16—16c, it will be seen that the main primary driving cam 48 has integral therewith a subsidiary cam 73 constructed for instance in the manner shown in Fig. 14. The latter is urged by spring 72 against the case hardened runner 77 which forms part of the bracket 84 on which is mounted the case hardened pivoting roller 85 and which is conveniently secured to channel member 115 extending across the chassis as shown in Fig. 9. The roller 85 provides the main pivot of the driving strip and gives both a rolling and rocking point for the travel and rock of the driving member 76. The driving strip 76 is pivoted at one end on the same pivot 85 as the main and subsidiary primary cams and at the other

end carries a driving pin 87, it being understood that the pivot 86 is independent of the bracket 84 so that the driving strip and cam assembly is maintained in position solely by being urged by spring 72 against runner 77 and roller 85, spring 72 having a component of its pull lying between these supports so as to give pressure on each. In order to advance the primary carriage through one step the driving pin 87 is adapted to be given a substantially rectangular movement. The first stage is due mainly to the subsidiary cam being pressed against the slide plate 77 to cause the driving strip 76 to pivot about 85 and the pin 87 to engage with a tooth of the toothed driving member 66 as shown in Fig. 16*a*, the second stage which is due mainly to the main cam 48 due to its engagement with the roller 47 moving the pivot 86 away from the roller and so causing the pin 87 to advance the carriage driving strip 66 along the running rail 51 to the position shown in Fig. 16*b*, the third stage is the withdrawing of the pin from a ratchet after a complete step has been made to the position shown in Fig. 16*c*, due to the subsidiary cam and the runner and the fourth stage is the restoration of the pin back to the position shown in Fig. 16 due to the main cam and the roller.

In the normal postion, i. e. with the main cam 48 held by the catch 82/110 the subsidiary cam 73 is on its maximum radius as shown in Fig. 16.

When the control relay 74 is operated on seizure of the selector, the catch 82 will move to the left away from the stop 110, the amount of movement being such however that it will still remain in the path of the following stop 111. Cam 73 thereupon rolls on slide plate 77 under pressure of spring 72 and cam 48 rotates with it for a short movement, further rotation being prevented by the engagement of stop 111 with catch 82. This slight rotational movement brings the periphery of cam 48 a little nearer the roller 47 owing to its radius gradually increasing, but contact does not yet take place.

When the control relay releases in response to the first break impulse of an impulse train the catch 82 will restore to the position shown. In the engaging face of catch 82 a U-shaped recess is cut in such a position and of such size that the stop 111 will just pass through, and cam 48 will now continue to rotate forward under pressure of spring 72 until the increased angular movement brings it into contact with the driving roller 47 with which it will remain in frictional engagement for the remainder of the revolution.

The first effective stage in the rotational movement is reached when the subsidiary cam has moved from having its maximum radius in contact with slide plate 77 to where it comes to have its minimum radius in contact as shown in Fig. 16*a*. During this stage the pivot 86 will have moved to the left to cause the driving pin 87 to engage with the top tooth of the primary carriage 52.

From this point onward the radius of cam 48 in contact with roller 47 continues to increase, while the radius of the subsidiary cam 73 in contact with slide plate 77 remains constant so that the driving pin 87 is given a movement in a direction along the path of the teeth of carriage 52 which is advanced one step when the position shown in Fig. 16*b* is reached. This completes the second effective stage.

For the third effective stage the radius of cam 48 in contact with the roller 47 then remains substantially constant, while that of cam 73 in contact with slide plate 77 rapidly increases so that the driving pin is withdrawn to the position shown in Fig. 16*c*.

The fourth and final stage consists of the driving pin being moved back to the position shown in Fig. 16 and is effected as the continued rotation of the cam 48 with its radius in contact with roller 47 decreasing proceeds. At this stage the toothed plate 66 is one step higher up than shown in Fig. 16.

On the next operation of the control relay and its subsequent release a second cycle of operations as described is performed to advance the carriage a further step and so on until the carriage together with the wiper arms which it carries have been set to a position opposite the required bank level.

Referring again to Figs. 8 and 16 it will be seen that lying along the primary carriage is a retaining pawl 43 which is attached by a pivot to the secondary carriage 50 and carries a case hardened retaining pin 118 at its free extremity which engages a tooth in the opposite side of the primary carriage to the driving teeth. At the free extremity of retaining pawl 43 there is provided a projection 119 at right angles thereto which passes under the carriage so that its tip will co-operate with an edge of the primary driving pawl 76. The receipt of an impulse causes the primary driving pin 87 to perform a rectangular movement as described and as the pin moves inward into engagement with the primary carriage ratchet the projection on the retaining pawl in engaging with the driving arm pushes the retaining pin 118 out of its tooth as shown in Fig. 16*a*. When the driving pin has completed its forward travel and carried with it the primary carriage through one step the retaining pawl and its projection assume the position shown in Fig. 16*b*, while when the driving pin withdraws at the end of its travel as in Fig. 16*c* the retaining pin 118 drops back in to the next tooth, the distances between teeth being such as to permit this to take place so that one is always in engagement. These operations take place for each impulse of the impulse train, and it will be seen that a positive lock is at all times maintained on the primary carriage by the driving pin or by the retaining pin so that overshooting cannot take place.

From reference to Fig. 8 it will be seen that a projection 120 is carried on the primary carriage 52 and this in the normal position of the carriage presses on the upper spring set 121 associated with primary relay 74. Springs 121 constitute the off-normal springs which change their position when pressure is removed, to produce suitable circuit operations as soon as the primary carriage 52 commences its first step. They are, of course, not affected by operation of the primary relay armature which is effective only on the lower spring set associated with the relay.

At the end of the impulse train the circuit arrangements are such that the release magnet 78 is energised, whereupon the rail 34 secured to armature 32 raises the wiper arms 53 and 54 slightly at their tips to cause these tips to clear the toothed combs of the bank level into which they will be subsequently inserted. One arm of the release magnet armature carries a projection 38 (Figs. 8 and 10) which normally drops into one of the retaining teeth of the secondary carriage; when the magnet is energised this is

lifted upwards and out of the tooth. It serves to prevent the damage to the bank which would occur if the wipers could be driven in when they were not held upwards.

The secondary relay 75 is now energised to initiate a self-interrupted secondary driving movement, the circuit operations of which will be understood from the ensuing circuit description. The release of the catch 83 which forms an extension of the armature of relay 75 from engagement with pin 112 on the secondary driving cam 49 causes this cam to rotate and engage with the driving roller, whereupon the rotation of the main and subsidiary cam will proceed on the lines described in connection with the main cam 48 and subsidiary cam 73 under control of the driving roller and its local drive-engaging spring 64 until such time as relay 75 is released for instance when the outlet testing wiper which connects up therewith encounters a free outlet in the selected group in response to the step-by-step movement of the secondary carriage, which in being advanced carries with it the primary carriage and the wiper arms secured thereto.

The secondary carriage driving action is the same as for the primary carriage, the only difference being that cam 49 is adapted to produce a rectangular movement of the driving pin 63 for each half revolution it performs. A further difference, as previously mentioned, is that the rotation of the cam commences on operation of relay 75 and thereupon continues until such time as this relay releases and interposes its catch into the path of one or other of the rotating pins 112 or 113 according to which half-revolution of the cam is involved in the step concerned when the outlet testing wiper which connects up with control relay 75 encounters a free outlet. Fig. 15 shows an enlarged perspective view of the secondary driving arrangements in which, for the sake of clarity, the main driving cam is assumed to have been removed and which shows the essential shape of the subsidiary driving cam 61 which is adapted to engage with the case hardened runner 62, while the roller 65 serves as a pivot for the driving strip 60 carrying the driving pin 63.

As described in connection with Fig. 10 the secondary carriage retaining pawl 33 (Figs. 8 and 10) is attached by a pivot to the selector chassis and, as in the case of the primary retaining pawl 43, carries a case hardened pin 122 at its free extremity which engages into teeth in the opposite side of the carriage to the driving teeth. The projection 39 on this pawl passes under the secondary carriage in order to co-operate with the secondary driving pawl, but instead of being integral with the pawl as in the primary case it pivots on the pin and has a restoring spring 123 as shown in Fig. 10.

The step shown on the pivoted projection 39 normally engages with a stop 124 (Fig. 8) attached to the chassis in such manner as to hold the pin 122 out of engagement with the holding teeth. When the secondary driving pin 63 engages with the first driving tooth to initiate a step of the secondary carriage the projection 39 is driven inwards away from the stop on the chassis and then as the driving pin moves forward in the direction of secondary motion, the free end of the projection moves about its pivot in the same direction so that when the driving pin backs out of the ratchet at completion of the step the projection in following in sympathy will over-ride its stop and will so allow the retaining pin to drop into position to provide the positive lock feature described in connection with the primary movement.

Although not shown in the drawings, it will be understood that there is an extension piece on the long arm 51 of the secondary carriage 50 which normally engages with an operating roller for the secondary off normal spring set 41 (Fig. 10 and also Fig. 11 where it is shown partly broken away), whereby the latter is pressed when the carriage is in normal position and is released as soon as the carriage moves off normal to initiate suitable circuit changes.

As regards the secondary drive interrupter springs these will form the outer combination of the lower build-up of the secondary control relay 75 (Fig. 8) and their operating pin 125 will be adjacent the head of the driving strip 60. Hence when the driving pin moves into engagement and commences the forward driving movement the springs are allowed to make or break according to their function and to remain so until the driving pin withdraws at the end of the stroke. These springs are not used as interrupter springs in their normal accepted circuit sense, but simply indicate when the carriage is in motion. The only use that has been made of these in the circuits shown is to prevent the release magnet de-energising while the wipers are moving.

When the secondary motion is terminated by the release of the secondary relay the release magnet is de-energised to lower the wiper tips into the contact sets opposite which they have been positioned to effect the necessary connection between the incoming trunk and the selected outgoing trunk, while the stop 38 is again introduced into the retaining side of the secondary carriage ratchet.

From Fig. 11 it will be seen that the secondary retaining pawl 33 is in the form of a bell crank lever, the lower arm passing under the secondary off normal spring set 41 and engaging with a strip 126 attached to the release magnet armature, the end of strip 126 hooking behind the lever end of the pawl 33. When the magnet is de-energised the action of this strip is to withdraw the pawl and its pivoted head projection away from the secondary carriage so that the step on the projection will once again re-engage with the stop 124 (Fig. 8) on the chassis so that the retaining pin will be out of action with the secondary ratchet when the release magnet is subsequently re-energised to initiate release of the switch.

When this occurs the removal of the projection 38 from the secondary carriage entirely frees this carriage which thereupon rapidly restores to its normal position under control of the helical secondary carriage restoring spring 81 and carries with it the primary carriage.

The release of the latter has now to take place and this takes place as follows:

It will be seen from Figs. 8 and 8a that the primary retaining pawl 43 carries a spring-loaded pivoted piece 44 which is situated half-way down the pawl and this carries a similar step to the projection 39 on the secondary retaining pawl 33. In the normal position of the primary carriage the pivoted piece 44 engages with a small projecting arm 45 secured at right angles to and at the centre of the primary carriage by virtue of the contact between said arm and a pin secured in the pivoted piece 44. On the first primary step the arm will leave the pin but the

piece 44 will not move since it will engage with the stop 42 affixed to the release magnet assembly in the manner shown in Fig. 11. Each time the retaining pawl 43 is moved about its pivot away from the retaining teeth of the primary carriage during the primary step-by-step movement, the outward movement performed by the piece 44 which moves in sympathy with the pawl 43 will be insufficient to cause the step thereon to engage behind the stop 42 so that during the primary stepping no locking action can be effected on the retaining pawl. When, however, the secondary carriage 50 makes a step and carries with it the primary carriage 52 and also the primary retaining pawl 43 which is pivoted on the secondary carriage, the movement involved by the first step will be sufficient to allow the step on the pivoted piece 44 to drop behind the stop 42.

Hence, after the secondary release has taken place as described above, the step comes into action as shown in Fig. 8*b* and disengages the primary retaining pawl pin 118 from the primary carriage so that this carriage will restore to normal under the tension of the associated helical restoring spring 80. The pivot piece 44 will then be disengaged by the projecting arm 45 on the primary carriage and which in the normal position of the carriage will engage with the pin secured in the piece 44.

On being disengaged from behind the stop 42 the pivoted piece allows the primary retaining pawl 43 to reengage its pin in the primary toothed plate and the switch is mechanically ready for a subsequent setting operation.

Two further types of release are available for use on special circuits, one in which primary release takes place without any secondary movement, and the other, secondary release without involving restoration of the primary carriage.

For this function the stop 42 on the release magnet assembly is secured thereto by a pivot as shown in Fig. 11 and on the energisation of the release magnet the strip 126 secured to the magnet armature on moving inwards away from the extension piece 127 secured to stop 42 will allow the stop to rotate under pressure of a spring (not shown) about its pivot whereupon its top will move towards the primary carriage so as to give an effect equivalent to the movement of the secondary carriage off-normal. Hence when release after a primary movement only is required, the release magnet is energised as soon as the switch is moved off normal or at any time before the secondary movement has commenced. When the magnet is released stop 42 restores to its normal position and the primary pawl is therefore pulled out of engagement with the primary ratchet and the carriage thereupon restores.

For secondary release the same parts and adjustments are required. The release magnet circuit is completed through secondary off normal springs so that under ordinary conditions when the secondary carriage gets home the release magnet restores and pulls out the primary pawl so that the primary carriage now releases to restore the switch fully to normal. When secondary release only is required the release magnet is maintained via a subsidiary circuit so that on restoration of the secondary carriage the primary pawl is not pulled out and the selector can be further stepped in a primary direction and then in a secondary direction into another level.

Referring now to Fig. 14 which shows a sectional view of one form of main and subsidiary cam assembly, say, that associated with the primary drive, it will be seen that the assembly comprises two pressings 68 and 69, each of, say, 20 mil steel. One, 68, which forms the outer surface of the main cam 48 on the subsidiary cam 73 is on one side while the other, 69, is a force fit inside the outer one 68 and takes the other side. The two halves are also held together by the bronze bearing 67 which is dropped inside before the halves are pressed together and then spun over outside. Alternatively, the main and subsidiary cams might comprise a suitable moulded plastic. The pins 110, 111, 112 and 113 of the cams might consist of a piece or pieces pushed up at right angles from the side material of the cam or may comprise a pin or pins moulded in the cam if the moulded cam construction is adopted.

It has already been mentioned that instead of escapement control of a driving cam a simple catch construction could be utilised in conjunction with suitable circuit arrangements as previously described.

For instance, if a condenser was discharged into the controlling electromagnet, the electromagnet would only operate momentarily and restore to hold the drive until a fresh impulse is received. By this modification the primary and secondary cams can be identically controlled or alternatively if the controls differ as described the secondary movement can be controlled both by dialled impulses and by hunting to find an idle line of a group.

For the purpose of indicating when the secondary carriage has completed its full travel the springset nearest the chassis on the secondary control relay 75 will be utilised and will be operated by a suitable projection on the secondary carriage when this carriage reaches the 11th step position.

As regards the selector wiring, it is thought that this might be effected with pre-formed cables. This can be considered as starting at the plug 37 (Fig. 17) and entering the chassis through an ebonite bushed hole 133. Immediately inside the chassis one branch will extend direct to the primary drive, while the other branch continues to the release magnet and the springsets located within the chassis, and it will also extend out through another bushed hole to cater for the secondary drive.

From Fig. 17 it will be seen that the switch plug 37 engages with a jack 71 which is screwed to the vertical bank member 13. The jack 71 is mounted on two separators giving sufficient clearance between the jack and the vertical member to accommodate one arm of the selector chassis when it is slid into position. As regards the jacking-in and jacking-out of the selector, reference should be had to Figs. 8, 11, 15 and 17 and it should first be appreciated that the secondary drive including the control relay 75 is assembled on the U-shaped angle piece 39 (Fig. 15) and is readily detachable from the selector chassis, the control relay being electrically connected with the rest of the selector circuit via a branch of the pre-formed selector wiring cable. With the selector in position against the bank as shown in Figs. 8 and 17 the plug 37 at the end of chassis arm 31*a* engages jack 71 while an L-shaped shoulder piece on the same arm will engage a locating pin 128 (Fig. 17) in the bank upright 17. The other arm 31*b* of the chassis is of substantially L section and will at its slotted

end engage with the extended bank clamp rod 16 while the nut 129 (Fig. 8) will be tightened up to secure both the chassis arm 31b and also the bank (at this selector) to the supporting member 130 which connects with the relevant exchange mounting upright. Also engaging the clamp rod 16 at this point will be one slotted end of the angle piece 89 (not shown in Fig. 8), the other slotted end of which will engage a locating pin in the chassis arm 31b. Hence when it is desired to jack-out the selector it is first of all necessary to loosen off the locking nut 129 and then with one hand to hold the secondary unit in position while with the other hand the chassis is withdrawn. During withdrawal of the chassis the secondary unit can be tilted inwardly so that it will clear the roller drive and it can then be withdrawn as well, this unit and the chassis being, as previously mentioned, linked by the wiring cable. When the selector is to be jacked-in the opposite procedure is adopted so that the secondary unit is firstly manoeuvred into position and is followed by the coupled chassis after which the locking nut 128 is tightened up.

The carriage mechanism of the switch can be readily detached from the chassis for maintenance purposes. When rubbing wipers are employed this detachment may be obtained by employing a compact form of plug and socket in the circuit of the wiper cords.

A further point which should be noted is that although as at present described the wiper tips perform two linear movements at right angles to one another followed by a slight movement of rotation when a selecting operation is being effected, the invention also envisages the case where the last "push-in" movement is also linear and at right angles to the first two main setting movements.

Turning now to the circuit arrangements, certain of the principles have been already laid down, and to these another will be added. The group and final selectors are to be kept as simple and standard as possible, and all variations are to be made in the battery feed relay set which is jacked in as a separate unit and serves to control successive switches. Apart from the question of standardisation one of the main advantages of this type of layout is the fact that any new technique can be introduced without affecting the mechanical parts of the exchange. One example of this as is described later is shown in the introduction of the speed timing type of impulsing circuit (United States application Serial No. 434,762, now Patent No. 2,334,591, dated November 16, 1943) by means of which impulse-responding circuits are adapted to function independently of the ratio of received impulses, the separate time measuring functions of the ordinary B and C relays being combined into one timing function which simply measures the overall length of each impulse instead of the length of the separate parts thereof as hitherto. With the normal type of exchange layout it would be necessary to modify every selector in the exchange to introduce this feature. Now it can be incorporated or omitted merely by changing the first relay set. With the increased lengths of connection over which dialling is being effected and the more general use of A. C. methods, this point is very important.

Detailed circuit consideration of Figs. 6 and 7 will now be given and it will be understood that when the switch is to function as a group selector, i. e. with dialled primary movement and self-driven secondary movement, and is to be controlled from a simple control circuit such as that of Fig. 7, then the primary driving cam will have to be of the two-stage escapement release type while the secondary driving cam will have to be of the single stage simple release type.

When a subscriber calls the control relay set or group of Fig. 7 is associated with the calling line via any suitable apparatus which might conveniently be of the line finder type. Relay A therein operates, whereupon the selector switch permanently associated with the control relay set is prepared for operation by the extension of earth forward over the negative and P leads. The earth on the negative lead operates the primary control relay VR, corresponding to relay 74 in the foregoing description, which at contacts *vr1* prepares a locking circuit for itself on to the private P. The armature extension on relay VR allows the associated driving cam to rotate slightly to the second stop position and when relay A drops at the beginning of the first impulse relay VR releases in turn and frees the driving cam. Under local spring pressure it rotates further and engages with the roller and thereupon completes a revolution independently of the control relay VR as already described. On the next and subsequent impulses of the train the primary carriage is operated in a similar manner to cause it to advance a number of steps corresponding to the digit dialled and it will be noted from Fig. 7 that relays B and C are held operated throughout the train by virtue of their slugs, the B relay guarding the connection and maintaining the P lead earthed while the C relay maintains the Z lead open to prevent the premature operation of the release relay ZR which is connected up to the Z lead on the first primary step due to the mechanical operation of the switch off normal contacts N1.

At the end of the first impulse train relay C releases after its slow release period and energises relay ZR which lifts the wipers clear of the bank level in question and at contact *zr2* provides an operating circuit for the secondary control relay RR. This relay in operating locks relay ZR at contacts *rr1* and also releases the catch on the secondary driving cam which engages with the roller. In this case the catch arrangement between the extension of the secondary relay armature and the driving cam is not of the escapement type, so that the motion continues until halted by the release of the relay RR and the consequent interposing of the tip of the extension armature into the path of the stop on the driving cam. The local drive-engaging spring periodically assists in maintaining the motion when the main cam passes through the position illustrated in Fig. 16. The secondary carriage advances step-by-step and carries with it the primary carriage and the wiper arms secured thereto are cause to enter step-by-step into the selected bank level. On the first secondary step the secondary off-normal contacts NR1 and NR2 are mechanically operated so that the holding circuit of relay VR is transferred to the P lead at contact NR2 and is locked for the remainder of the call via resistance VRR.

At the end of each secondary step the operating circuit of relay RR is broken by the interrupter contacts *r1*, which it will be understood are made during the engagement of the secondary driving pawl with the secondary ratchet, but when this occurs it will be noticed that the second winding of this relay will be connected over a rubbing test

wiper P on to the corresponding lead of an outgoing trunk. If such a lead is busy an earth potential will be encountered thereon so that relay RR will remain held and the secondary carriage will step on to the next set of outlets.

When a free set of outlets is encountered the P wiper will not encounter any earth potential and the interrupted contacts *r*1 on opening will cause relay RR rapidly to deenergise and the catch on its armature will thereupon fall into position to halt the secondary movement when the cycle of movement of the cam is completed.

Relay ZR is now released and causes the wiper arms to drop so that the tips thereof will lower into the set of selected bank contacts to press the movable contacts against the fixed contacts in the contact bank and so causing the calling party and the battery feed relay set to be switched through to the succeeding selecting stage, which may be either the final selector stage or another group selector stage. If the latter the operation will be the same as previously described. If the former the operation of the battery feed relay set will be as described except that it will function twice while the circuits will be appropriately modified from those shown in Fig. 6. More detailed circuits are described later with reference to Figs. 19 to 22.

If the calling party should now hang up, relays A and B in the control relay set will release and the removal of earth from the P lead will release relay VR, whereupon an operating circuit for relay ZR is re-completed via contacts *vr*2 and NR1. The wipers are again lifted clear of the bank and as previously described, the primary and secondary carriages are now freed to restore to normal under local spring tension. The mechanically operated springs restore to normal and at contact NR1 relay ZR is released to render the selector ready for further use.

As regards the succeeding selector, on seizure its primary control relay will have been operated over the negative lead and on release of relay A the control relay is released and initiates a single primary step. When relay B releases relay C releases following relay B and the selector release relay is energised and operates the secondary control relay whereupon a self-driven secondary movement commences. When a free outlet is encountered or when the 11th step position is reached where contacts equivalent to contacts S1 (Fig. 6) are operated the secondary control relay releases to stop the drive and in turn releases the release relay. The release relay in restoring opens the holding circuit for the primary control relay which has been held during the secondary movement and the latter in restoring re-energises the release magnet whereupon the switch restores to normal in the same manner as has been described for the preceding selector.

If all outlets on a level should prove to be busy the wipers will advance to the 11th step position in which position the 11th step contacts S1 will be mechanically operated and will open the circuit of relay RR to halt the secondary motion in the same manner as for a free outlet so that the switch will contact the control relay set through to the 11th set of bank contacts. It will be understood that the 11th step positive contact is permanently earthed so that earth will be extended back over the positive lead to the control group which in response thereto will initiate the return of a busy tone to the calling party in a manner discussed later. If an overflow for the level is to be provided this could be connected to the 11th step P contacts and the contacts S1 in operating could be in the form of a changeover combination adapted to extend earth forward over the rubbing P wiper to operate the overflow meter in this condition.

Consideration will now be given to the battery testing types of selector switches in which the idle condition is indicated not by the absence of earth but by the presence of negative battery. Such switches normally involve more relays than the earth testing variety, since the fast cut drive relay could not operate quickly enough if it carried the switching load and a relief thereon must therefore be usually provided. In the present instance however, no more relays than usual are required, since the cut drive relay can be located in the control relay set, while the switch banks themselves provide the switching function.

The circuits of a ten level ten outlet per level (10/10) battery testing group selector (Fig. 19), a 10/10 regular final selector (Fig. 20) and of a 10/10 P. B. X final selector (Fig. 21) with P. B. X groups of 2–10 lines will be considered in turn in conjunction with the control relay set circuit of Fig 22.

The circuit arrangements of this relay set are such that regardless of whether the secondary movement of a switch is to be under dialled impulse control or to be self-driven in response to an initial stimulus, the secondary cam may be of the simple catch release type. This feature could also be applied to the primary movement were it not for the fact that the primary control relay also serves to hold the switch by being maintained from the P lead after initiation of the secondary movement, its subsequent restoration bringing about release of the switch.

On examination of the circuits of the battery feeding and control relay group of Fig. 22 it will be noted that the ordinary A. B. C. impulse-responding group employed in the basic control circuit of Fig. 7 is replaced by the speed timing impulse-responding circuit shown and described in the prior United States application Ser. No. 434,762, now Patent No. 2,334,591, dated November 16, 1943, this having been done in order to avoid the use of the normal timed B and C relays and also because it may be said that the present standard impulsing methods have about reached the limit of their usefulness as evidenced by the increasing use which is being made at present of electro-mechanical impulse regenerators in telephone exchange systems. In speed timing arrangements the impulse speed is measured instead of impulse ratio as hitherto, so that line conditions, which have a distorting effect on impulse ratio but not on their speed, are now an almost negligible consideration.

The speed timing circuit comprises a single time measuring circuit including a condenser QD, resistance YO and neon tube NT and is adapted to compare the total length of the make-plus-break period of each impulse of a received train with a predetermined period of the order of 150 milliseconds which is substantially equal to the total length of each impulse at the lowest impulsing speed tolerated in practice.

The circuit is set into operation at the beginning of the first impulse of a train and is restored to normal by each successive impulse of the train until the last pulse is received, after which it functions either to initiate release of the connection or to render the circuit of the switch in question ready for the further function required of it according as to whether the impulse

train finished with the impulse accepting relay normal or operated.

When a calling subscriber is connected through to the control group, relay AA operates, and at contacts *aa1* brings up relay BB, while contacts *aa2* rapidly charge up condenser QE to the exchange battery voltage via resistance YM. Relay BB in operating at contacts *bb7* places a guarding and holding earth on the incoming P lead and at contacts *bb4* extends earth potential out over the outgoing (right hand) negative lead to operate the primary relay 1VR in the first group selector associated with the control group, the circuit for which is shown in Fig. 19.

Referring now to Fig. 19 relay 1VR in operating at contact *1vr1* disconnects the idle resistance marking battery comprising the battery connected resistance YA which is normally connected to the P lead to indicate the free condition of the switch to a preceding hunting switch where such a switch is involved. The armature extension of relay 1VR allows the associated driving cam to rotate slightly to the second stop position and the switch is now ready to receive a train of impulses.

Meanwhile relay BB in operating at *bb2* connects up dial tone over common lead DTE to the centre winding of relay AA and the dial tone extends by induction on to the incoming speaking leads and thence to the calling party.

When relay AA releases on the first impulse of a dialled train relay E energises in series with relay B which is thereby held. Relay E in operating at contact *e4* brings up relay MD which at contacts *md3* disconnects the dial tone circuit and locks via contacts *md1*, *d3* and *bb5* to earth. Contacts *aa2* allow the charged condenser QE to discharge through relay HR which operates, the size of this condenser being so adjusted as to allow contacts *rh3* in the earth circuit to the negative wire to interrupt this circuit for a period long enough to release the selector relay 1VR and so to free the driving cam and cause the selector to proceed to perform one primary step. This rather unusual method of impulse repetition which is more correctly regeneration in another form is primarily adapted to operate in conjunction with the secondary movement simple catch release control so that this movement may be controlled by dialled impulses or may operate independently in a self-driven circuit according to the function required of it. Details of such operations will be given later.

When relay AA re-operates at the end of the first impulse relay BB remains held via relay E in parallel with resistance YL, relay E also remaining operated under this condition and at contacts *aa2* condenser QE is rapidly recharged via resistance YM. The second break impulse of the train therefore re-operates relay HR for a short period in the same manner as for the first, and the second momentary break is made in the earth circuit over the negative lead to the selector relay 1VR, whereupon a second step is delivered to the selector. This happens for each succeeding impulse of the train until at the end of the train relay AA remains operated for the comparatively long interdigital pause period.

During this period the initiation of the selector secondary movement is performed by the impulse speed timing circuit in the following manner. On the first operation of relay E, i. e. at commencement of the first received break impulse, a charging circuit for the speed timing condenser QD is prepared at *e3* via resistance YO to positive battery and when relay HR releases after extending the momentary break impulse to the selector condenser QD starts to charge. The respective values of the resistance and condenser are such that the condenser takes approximately 150 milliseconds to reach a voltage large enough to flash the neon tube NT. More precisely, the charging period is 150 milliseconds less the operated time of relay HR which operates for a given time period at commencement of the break period of each received impulse.

If the second break period is received before the elapse of 150 milliseconds from the commencement of the first break period then relay HR in again operating at contacts *hr1* will rapidly discharge condenser QD via resistance YM and the charging up of this condenser will recommence on the release of relay HR. The discharging and charging of condenser QD occurs for each received impulse until at the end of the train relay AA remains operated and allows the voltage of condenser QD to reach the flash voltage of neon tube NT 150 milliseconds after the commencement of the last break impulse of the train.

Neon tube NT in flashing brings up relay CC and this relay in operating locks over its upper winding in series with resistance YM and *e2* and at its contacts *cc1* disconnects relay E which commences to release slowly. At contacts *cc2* battery via the winding of relay D is fed out along the Z wire and since the selector primary off-normal contact 1N2 will have closed when the switch stepped off normal in a primary direction this battery potential extends through to the combined release magnet and relay 1ZR. Relays D and 1ZR operate under this condition.

Relay 1ZR in operating lifts the switch wipers clear of the level of contacts into which they are to be inserted and at contacts *1zr1* operates the secondary control relay 1RR from the earthed negative lead to initiate the self-driven secondary driving movement of the switch in search of a free outlet to a succeeding switch.

Relay 1RR in operating initiates the secondary drive by freeing the catch on the secondary driving cam and locks relay 1ZR via contacts *1rr1* to battery via resistance YC. On the first secondary step the secondary off normal contacts 1NR1 and 1NR2 are operated, the former disconnecting the initial operating circuit of relay 1ZR so that relay D in the control relay set releases without having effected any circuit operation at this stage; at contacts 1NR2 the holding circuit for relay 1VR is transferred to the earthed P lead.

Contacts *1zr2* connect the rubbing private test wiper RW1 through over the positive trunk and thence via resting contacts *f7* and *h7*, operated contacts *cc5* and resistance YQ to the upper winding of the fast cut-drive relay HR.

When the rubbing wiper RW1 encounters an idle outlet as indicated by an idle resistance marking battery such as that normally connected to the P wire of this switch, relay HR rapidly operates and at contacts *hr3* disconnects the earth potential being fed out on to the negative lead, whereupon relay 1RR releases to stop the switch motion and at contacts *1rr1* de-energises relay 1ZR to drop wipers into action with the banks so as to switch the control relay set through to the succeeding selector stage. The control group relay H has not enough time to operate at this stage, for a reason to be later described.

The secondary drive interrupter contacts 1*r*1 function in the same manner as for the earth testing group selector case previously described.

Returning again to the control relay set it will be noted that when relay CC is operated to initiate the secondary movement it remains locked either until the expiration of the slow release time of relay E when its locking circuit is opened at contacts *e*1 or of the time required to find a free trunk when its locking circuit is opened by contacts *hr*1, whichever is the longer.

When the selector relay 1ZR is disconnected to switch the control relay set through to the succeeding selector stage contacts 1*zr*2 open the outlet testing circuit and so release relay HR in the control relay set, the succeeding selector taken in use being guarded by the extension of earth thereto over the P wire from the control relay set. On release of relay CC the control set will be in readiness for the dialing of the next digit to control the positioning of the succeeding selector now taken into use.

If the subscriber should now hang up relay AA will fall and relay E will operate in series with relay BB which holds. Condenser QE will be discharged through relay HR and a single impulse will therefore be sent out over the negative wire to the succeeding selector. Approximately 150 milliseconds after the release of relay AA the speed timing circuit will come into operation, whereupon relay CC operates and since relay AA is now normal the holding circuit of relays E and BB is disconnected and the former will commence to release slowly due to its slug while the latter will release comparatively slowly due to its non-inductive resistance shunt involving resistor YN. On release of relay BB the locking circuit for relay CC is opened at *bb*1 and on release of relay E the holding earth is removed from the P lead at *e*1 whereupon relay 1VR which has been previously held is now released and at contacts 1*vr*2 completes a re-operating circuit for relay 1ZR, whereupon release of the group selector is effected in the same manner as for the previously described earth-testing group selector.

As regards the succeeding selector, on seizure its primary control relay will have been operated over the negative lead and on the release of relay AA the momentary break in the earth potential extended on to this lead causes the primary control relay to release to initiate one primary step. 150 milliseconds later relay CC operates, and during the slightly slow to release time of relay BB battery potential via the winding of relay D is fed out over the Z lead to bring up the release relay and the secondary control relay is now operated from the negative lead on to which the earth will have by this time been replaced. The switch now cuts in and proceeds to complete the first secondary step and if relay BB should release during this time then it will be seen that the interrupter contacts equivalent to 1*r*1, which are made during the stepping operation, maintain the release relay independently of the now normal secondary control relay. At the end of the step the interrupter contacts open and release the release relay, whereupon the incoming leads to the selector will be switched through to the set of outlets opposite to which they are positioned, but it will be noticed that since relay BB is normal the seizing negative lead will be disconnected in the control group. On release of relay E the selector primary control relay is released due to removal of the earth from the P lead and the release relay thereupon re-energises and initiates release of the switch.

Returning now to the operation of the group selector of Fig. 19, if all outgoing trunks should prove busy then the secondary movement will continue until the rubbing wiper RW1 reaches the 11th step position, the P contact of which is permanently wired to a resistance battery so that the cut-drive relay HR will operate to release the secondary control relay 1RR and so halt the rotary motion. Relay E will have released by this time and hence relay HR in operating will release relay CC and contacts *hr*1. In the selector relay 1RR in releasing releases relay 1ZR and the 11th step contacts 1S1 thereupon become effective to extend earth back over the positive lead to bring up relay C in the control group. Relay G in operating locks over its contacts *g*1 and at contacts *g*2 connects up a busy tone earth source over common lead BRE to the centre winding of relay AA from whence it is returned to the calling party.

As regards the 11th step P contact the outgoing P contact of which is permanently wired to resistance battery, it will be understood that the incoming P contact of the bank switching pair will have been removed so that when the wiper arm is dropped on the release of relay 1ZR the outgoing contact will not be earthed from the control relay set and further selectors can therefore switch to the same battery. On the release of relay 1ZR the 11th step contacts 1S1 also become effective to extend earth to an overflow meter which will be connected to the 11th step outgoing positive bank contacts.

It should be noted that when controlling a group selector the negative battery encountered by the rubbing wiper RW1 when an idle succeeding switch is encountered is removed some 10 milliseconds after the operation of relay HR, i. e. when the selector relays 1RR and 1ZR release in turn, and for this reason relay HR is given a locking circuit via contact *cc*4 and *hr*2 to ensure the release of relay CC in case during a secondary hunting movement relay E should not release before relay HR operates in response to the encountering of a free outlet. The switching relay H, a winding of which is in series with the operating winding of relay HR, will be given an operating time longer than this 10 milliseconds period to ensure that it will not operate when the control set is governing the setting of a group selector; under conditions where the control set is governing the setting of a final selector relay H will be given ample time to operate as will be later described.

Assume now that when the group selector has been seized the subscriber hangs up without dialling. In this case an impulse train of a single impulse is simulated but with relay AA remaining normal at the end of the impulse. The release of the selector follows along precisely similar lines to that of the succeeding selector when the calling subscriber hung up after dialling one digit only.

It will now be assumed that the succeeding selector taken into use is a regular final selector, circuits of which are shown in Fig. 20 from which it will be seen that the bank switching portion which is the same as in Fig. 19 has been omitted.

On seizure the primary relay 2VR is operated and the initial operation of this switch up to the energisation of the release relay 2ZR at the end of the first received train of impulses is the same as for the group selector of Fig. 19. Relay 2ZR

in operating connects the secondary relay 2RR up to the earthed negative lead, but in this instance since relay 2RR is connected to earth instead of battery it will remain normal due to the shunting action of the earth on the negative lead, which earth also serves to hold the vertical relay 2VR. Hence no automatic secondary movement takes place and the control group relay D remains held in series with relay 2ZR.

When the next train of impulses is received by the control group, then each time relay HR operates for a short period at commencement of the break period of an impulse the earth potential to the negative lead is replaced by a battery potential via resistance YP and the selector secondary relay 2RR for each received impulse, is operated for a length of time governed by the operated time of relay HR.

It will be remembered that the secondary driving cam is of the simple catch release type and hence in order that dialled impulses may be effective thereon it is necessary to ensure that the control relay 2RR after having been operated in response to an impulse shall release in time to put a stop in the path of the secondary cam before this cam has completed the one half revolution necessary to advance the wipers through one step; for this purpose the length of the secondary pulse as governed by relay HR is arranged to be less than the 30 milli-second period required by the cam to complete one half revolution. Each successive pulse is similar to the first and the carriage is thus dialled step by step into the bank.

In the control group at the end of the first impulse train relay CC in operating initiates the slow release of relay E in usual manner, while relay BB remains held. One locking circuit of relay CC is opened by operated contacts *d1* so that when relay E releases after its slow release period relay CC will immediately restore and the circuit is now in readiness for the next dialled digit.

When relay CC again operates at the end of this next digit the earthed testing relay HR and the switching relay H are connected up in series over the positive wire and thence via contacts *2zr2* and the rubbing private testing wiper RW1 to the called subscriber's P conductor.

If the called line is free a resistance battery marking will be encountered on this conductor and relay HR will operate in series therewith; in this case, as distinct from the group selector, since the selector relay 2ZR is locked up to relay D relay HR in operating will be unable to cause the release of relay 2ZR, and accordingly the switching relay H will get time to operate during the slow-to-release time of relay E which will have again commenced to release slowly on the operation of relay CC. On all final selector switches (ordinary and PBX) three leads extend to the line circuit of each subscriber concerned, the negative and positive outgoing bank contacts connecting with the corresponding negative and positive leads of the line circuit, while as regards the subscribers' private leads, these connect up with the outgoing Z bank contacts, the outgoing P bank contacts not being wired out. Hence, when relay H operates contacts *h5* extend earth forward over the Z wire to short circuit and release the final selector relay 2ZR and so effect the switching through of the control set to the called subscribers' line. The earth will also extend forward over the switch banks to the called subscriber's private wire to mark this line as busy and so effect the necessary control in the subscriber's line equipment to receive the incoming call. The connection to the called subscriber's private wire is initially over wiper RW1 and subsequently when 2ZR is released over the main contacts.

Contacts *h4* and *h7* respectively, connect up an earthed ringing generator GNR via the winding of relay F on to the negative line and a ringing return battery via lead RRB and resistance YS on to the positive line so as to ring the called party's bell, while contacts *h2* connect up a ringing tone earth source over lead RTE to the centre winding of relay AA from whence the ringing tone returns to the calling party.

When the called subscriber replies relay F operates and at contacts *f1* removes the short circuit from its right hand winding over which it locks, while at contacts *f6* and *f7* the ringing is tripped and the battery feeding relay D is connected at *f4* and *f5* across the outgoing lines and through to the called party. Conversation may now proceed.

It will be remembered that relay MD was operated from relay E when the latter operated in response to the first train of impulses received by the control group and when relay D operates it will be seen that the holding circuit for relay MD is opened at contacts *d3*. On release of relay MD after its slow release period a battery potential via resistance YK is extended backwardly over the metering lead M to register the call against the calling party.

At the end of conversation when the calling party hangs up relay AA releases, whereupon relay E operates in series with relay BB which holds. The speed timing circuit comes into operation and 150 milliseconds after release of relay AA relay CC comes in and initiates the slow release of relays E and BB. On release of relay BB relays H, F and D are released, while on release of relay E the holding earth is removed from the P lead and the various primary control relays in the selector train which have been held therefrom are released so as to bring up their release relays and so initiate release of their respective switches.

Assuming now that the required line proves to be busy then relay H will fail to operate during the release time of relay E and when relay E releases relay CC will fall and will connect up relay G on to the positive lead. Relay G thereupon operates to the earthed busy subscriber's private encountered by rubbing wiper RW1 and returns busy tone to the calling party at contacts *g2*, while at contacts *g4* the circuit for extending battery potential via the winding of relay D on to the Z lead is opened and the final selector release relay 2ZR thereupon releases. The final selector wiper arms are thereupon lowered into contact with the bank but it will be appreciated that interference with the busy required subscriber is guarded against by the disconnection in the control group of the negative, positive, and Z wires at contacts *g5*, *g1* and *g4* respectively, which wires are, in the case of all final selector switches, respectively connected up at the final selector switch banks to the subscriber's negative, positive and P leads. The P lead from the control group and through the selector train to the final selector remains earthed for the purpose of holding the selector train until the calling party hangs up, and since the P lead does not extend through to the subscriber's line circuit it can do so without interference to the line of required subscriber.

It will now be assumed that the last two dialled

digits are effective on the 2–10 line P. B. X final selector shown in Fig. 21. The primary and secondary setting of this switch is the same as for the regular final selector but in this case when at the end of the last impulse train the secondary control relay 3RR is released from the control group and when relays HR and H are connected in series on to the positive trunk and hence via operated contacts *3zr2* and resting contacts *3rr1* the rubbing test wiper RW1 and the contact it is resting on to the private wire of the line circuit in the wanted P. B. X group to which the final selector wipers have been positioned. The contacts engaged by RW1 are connected to the outgoing Z contacts which as in the case of the regular final selector are connected through to the subscriber's private wire. It will be noted in addition that the Z wire is connected through to a corresponding contact on an auxiliary bank via the off normal contacts 3N2, condenser QA, contacts *3zr3*, contacts *3rr2*, and the rubbing wiper RW2. The auxiliary bank which is only used for testing purposes may comprise the outgoing P bank contacts which on the final selector are normally unwired while the outgoing X contacts connect through to the subscribers' privates. On this auxiliary bank it will be understood that the first lines of P. B. X groups are marked by a source of battery with alternating current imposed, on intermediate lines the outgoing P and Z contacts are strapped, while on the last lines a resistance battery is connected.

If the switch wipers are positioned to the first line of a P. B. X group the battery connected alternating current source encountered by wiper RW2 extends back via condenser QA and the Z lead to operate relay HS on its left hand winding in series with resistance YP, this winding of relay HS being arranged in association with condenser QF and rectifier MRA so as to operate satisfactorily on alternating current. Relay HS in operating at contacts *hs2* maintains a holding circuit for relay E so that relay CC in turn will remain locked after operation from the speed timing circuit, while at contacts *hs1* it prepares for the extension of battery potential via its other winding on to the negative lead.

If the line is found to be free by test wiper RW1 the free line battery potential will extend back over the positive lead to bring up relay HR. In this case the operation of relay HS will be without effect as the circuit to the negative lead is opened at contact *hr3*. Relay H in operating after the operation of relay HR will, in a manner as already described in connection with the regular final selector, cause the P. B. X final selector to switch through to the first line on the P. B. X group after which ringing is carried out in the manner already described.

If the line is busy however, relay HR will fail to operate and the resistance battery extended on to the negative line via the right hand winding of relay HS will bring up the selector secondary relay 3RR to cause the switch to hunt automatically over the lines in the group.

With relay 3RR operated it will be noted that at contacts *3rr1* the positive wire is transferred from the testing wiper RW1 to wiper RW2, but on intermediate lines of a P. B. X group it will be remembered that the associated P and A outgoing bank contacts are strapped so that during movement the control group will still be virtually testing over the subscribers' privates of the group. It will be appreciated that the alternating current circuit over wiper RW2 can operate independently of the D. C. holding circuit for relay 3ZR since it is isolated therefrom at the selector by condenser QA and at the control group by condenser QF. When a free intermediate line in the group is encountered relay HR energises and releases the selector secondary control relay 3RR to stop the movement. Relay H then operates and functions in the manner already described to cause the lines to be switched through.

If the first and intermediate lines of the dialled P. B. X group are engaged the selector on reaching the last line will at its wiper RW2 encounter a resistance battery potential which marks the last line of all P. B. X groups. Accordingly, relay HR will operate over the positive lead and over operated contacts *3zr2* and *3rr1* whatever the condition of the corresponding line (the relevant outgoing P and Z contacts not of course being strapped on the last line of a P. B. X group). Relay HR in operating at contact *hr3* opens the locking circuit of relay HS which in releasing at contact *hs2* opens the holding circuit of relay E which commences slowly to release. The disconnection of the battery via the winding of relay HS to the negative lead (relay CC still being held from relay E) will cause the switch secondary relay 3RR to release so that relays HR and H will be connected up in series over the positive wire to rubbing wiper RW1 and thence to the private of the last subscriber in the group so that if the line is free relay H will operate to effect connection with the called line. If the line is busy relay H will fail to operate but relay HR will remain held over its lower winding to battery via resistance YM. On release of relay E after its slow release period relay CC will fail and will release relay HR, while at contacts *cc5* relay G will be connected up to the positive lead and will then operate to the busy earth potential encountered by the busy test wiper RW1 with results as already described.

In case a particular line out of a P. B. X group is required, as under night service conditions, then provided that this is not the first line of the group, if the P. B. X selector is positioned accordingly by dialling no P. B. X hunting will take place if it is found to be busy since relay HS will not have been operated to provide the conditions necessary for P. B. X hunting and the operations involved will be as for a regular final selector when an engaged outlet is encountered.

It is to be noted that the circuit of Fig. 21 can be used for a switch to function as well as either a group selector, final selector or P. B. X final selector by simply making appropriate connection to the contacts engaged by the rubbing wipers and in the case of a group selector arranging that the rubbing wipers RW2 engage a normal contact connected to alternating current supplied in series with battery as in the case of the first contact of a group.

Other points and additional features both in regard to the selector switches and the control group will now be discussed.

As previously mentioned the outgoing Z bank contacts in the final selectors connect with the P conductors of the subscribers' line circuits concerned so that when the control group switches earth will be extended forward over the Z wire from contacts *h5* to the P conductor of the subscriber in question. The Z wire is carried through between the control group and the final selector without shunt or series resistances, so that various facilities such as toll breakdown

which were originally provided from the final selector can now be provided in the control group.

If the circuits of the regular final selector and group selector shown in Figs. 19 and 20 are examined and compared, it will be seen that there is no reason why the final selector circuit should not be employed on the group selector provided that in the control group the Z circuit is opened to release magnet 2ZR by relay HR when it opens the circuit for magnet 2RR on an idle line being found. Certain other modifications will be required in the control group to ensure that relay HR does not open the circuit of 2ZR other than at the end of an impulse series or at the end of hunting. With such circuit modifications the necessity of maintaining the circuit of 2ZR by 2ZR3 is avoided and the circuit of Fig. 20 may be simplified by connecting 2ZR direct to 2NR. It is obvious that it is impracticable to illustrate all the modifications which are possible and it is only proposed to indicate generally the lines on which modifications may be made as a circuit designer skilled in the art can readily make the necessary complementary modifications. For instance when the primary movement has been concluded relay 2ZR will be operated as previously, and the control group will be arranged to extend a resistance battery out over the negative lead to operate relay 2RR via contacts of which the primary relay 2VR will be maintained temporarily until the secondary drive commences and the operation of relay 2RR will cause the secondary drive to take place. When a free line is reached the cut-drive relay HR will operate through the positive lead as before and will thereupon open the negative lead to drop relay 2RR and in this instance the Z wire will be also opened by contacts of relay RR to release relay 2ZR and so effect switching through to the succeeding switch. In the case where the control group will be working into a final selector it will operate almost exactly as shown and described.

In the case described with regard to Fig. 21 it is possible to insert the switch mechanism in any position in an exchange and it will automatically function in the manner required of it, i. e. as group selector, final selector or P. B. X selector. In the case of Fig. 20 it has been explained how this circuit can be adapted to be used either as a group or final selector but in this case a certain amount of discrimination is necessary. This discrimination may take two forms, one involving the modification of the circuit of the control group according to discriminating signals sent back to the control group according to the kind of switch taken into use so that the operation of the control group is adapted in each case to the kind of switch being controlled the other involving a modification of potentials applied to one or more of the magnet relays of the switch when it is plugged into position, for instance relay 1RR is connected in one case to battery potential and 2RR is connected to earth potential if the winding of 1RR or 2RR was connected to a pin of the jack and engaged with a terminal in the contact bank. This terminal could be connected to earth in the case of a final selector and battery in the case of a group selector. Discrimination in the first case may be effected by means such as a resistance inserted at the jack of the group selector and not at the jack of the final selector or vice versa. Proceeding along the lines indicated, one approves of the result that an identical detachable selector circuit is used for both group and final selectors in which case every selector in the exchange could either perform its secondary motion automatically or under the influence of dialled impulses according to the discrimination on the jack.

A group selector could furthermore be adapted to operate in the same manner as a P. B. X final selector, i. e. with an initial dialled secondary movement, and this facility might be used in connection with testing and routining functions and for special trunking arrangements. For instance, the selector can either start to hunt from the first bank contacts or can be dialled to a position on the bank and be caused to hunt on from there.

Another point arises in connection with the selecting switches according to the invention, and that is that they can be rendered self-routining, since each selector can derive from the driving roller the requisite trains of impulses at the rate of ten per second. An unlocking push button at the front of the selector could apply the impulses to the primary control relay in response to which the switch would step in a primary direction to say level 9, where mechanically operated springs would energise the release relay to cause the switch to perform a secondary hunting movement until contact 9 on this level is reached. Further springs would then be operated to halt the switch movement.

It will be noted that no mention has been made of P. B. X groups having more than ten lines. Such large P. B. X groups are the exception rather than the rule. In these cases it is proposed to employ selecting units catering for up to 100 lines and which by virtue of the use of one or more subsidiary relays are capable of performing hunting operations over a level, then of being released back again to the commencement of the level and stepped up to the next level where they perform another hunting operation, and so on; a method of achieving secondary release without primary release being described previously.

As regards the control group, it will be noticed that the speech transmission condensers are not introduced into the circuit until impulsing has been completed so that the distortion ordinarily produced therefrom, which is especially troublesome when impulsing over long junctions is avoided.

A facility which has not yet been described in connection with the control group is that of switching out the transmission bridge when the call is to be routed over an outgoing junction. This can be done in a simple manner which will involve relay contacts in the through leads but the following method now to be described in connection with Fig. 23 in which relay contacts in the through speaking leads to the outgoing junction repeater relay sets are entirely avoided, is proposed.

Referring to this figure, it will be understood that normally on a selector bank the comb plates relevant to each of the various leads, say, negative, positive and private, are strapped together behind the multiple, but where say levels 1—9 of a first selector are to give access to the local switching train, and where level "0" is to give access to outgoing junctions, the comb plate wiring may be split so that the incoming speaking leads will connect via contacts *og*3 and *og*4 of a relay OG via the control group of Fig. 22 with the comb plates 1—9, and will connect directly with the comb plates of level "0."

If any of the digits 1–9 are dialled, the selector train will be set up in normal manner under control of the control group of Fig. 22 as already de-

scribed, but if digit "0" is dialled for the purpose of an outgoing junction call, then the directly connected "0" level comb plates will come into operation as follows: When a free outgoing repeater is found, relay OG will be operated from earthed contacts *bb* of the control group relay BB over its left hand low resistance winding to the idle resistance marking battery which will be connected to the incoming P lead at the outgoing repeater, the low resistance winding of relay OG serving as a guarding potential and also to operate relay OG which thereupon at contact *og3* and *og4* disconnects the circuit to the control group. During the release of the control group, which will take place at approximately 150 milli-seconds after the opening of the loop thereto, when relay CC operates and releases relay BB, the subscriber's loop will be extended forward to operate the impulse accepting relay and in turn the guard relay in the outgoing relay set and a guarding and holding earth will be extended back to hold relay OG on its other winding, before relay BB in the control group which has previously been holding it, releases. The subscriber will now be directly connected through to the outgoing repeater which will receive the remainder of the trains of impulses to be dialled and which will provide the battery feed to the calling subscriber. The selector will of course remain held over the P lead from earth at the outgoing relay set which will extend via contacts *og2* and through the control group to the selector primary control relay.

The above arrangement can also apply to the case where the group selector has only one level giving access to the local switches in the exchange and the other levels all have access to outgoing repeaters leading to other exchanges the only difference being that instead of the control relay set leading to the first nine levels it will only be connected to the level leading to local switches while the other levels will be connected direct to the incoming leads. The circuit arrangements of Fig. 23 will equally apply to this arrangement. Similarly it is possible to arrange for more than one level to be used for the local switch train and more than one level to be used for connections to other exchanges again employing the circuit arrangements of Fig. 23.

Consideration will now be given to the question of inter-exchange working.

The impulsing improvements proposed in United States application Ser. No. 434,762, now Patent No. 2,334,591, dated November 16, 1943, such as self-correcting switch magnets and speed timing impulse responding arrangements provide a highly efficient arrangement for the receipt of impulses, but it is possible that when several impulse repetitions are concerned, no impulses at all will be received at the distant end.

So far a single exchange has been envisaged, and this exchange has been made such as to interwork into an existing area. In new areas a greater flexibility is possible, and it seems desirable to provide an impulsing scheme in which the present impulse repetition method is obviated.

For this purpose it is proposed that all inter-exchange impulsing should be of the alternating current type; holding and supervisory signals will still be on a direct current basis as at present, but alternating current pulses, preferably of voice frequency, will be superimposed on these to perform the actual movement of the selectors. In the case of tandem exchanges the received alternating current impulses will be converted to direct current impulses for the purpose of setting up the selector train in the tandem exchange and thereafter the necessary conversion unit will be cut out and the remainder of the alternating current impulse train will pass straight through to the terminating exchange in the same manner as for speech currents, the direct current supervision arrangements being retained.

Referring now to the basic D. C./A. C. outgoing repeater circuit shown in Fig. 24, when this is taken into use via a switching arrangement such as that shown in Fig. 23 relay 1A operates and is followed by relay 1B which at contacts *1b1* replaces the idle marking battery via resistance YX by a guarding and holding earth and at contacts *1b3* extends a D and I relay loop, either of normal type or of the thermionic valve type described in United States Application Ser. No. 446,900, now Patent No. 2,350,652, dated June 6, 1944 over the right-hand outgoing junction conductors to the distant office.

When a train of direct current loop impulses is received relay 1A responds and on each release condenser QJ is charged via contacts *1a2* and *1b2* to earth while on each reoperation relay 1PU is energised for the discharge time of condenser QJ. In response to the received train, flick impulses of alternating current are therefore extended over leads AC1 and AC2 and then contacts *1pu1*, *1pu2* and *1b3* to the outgoing junction, the D and I loop either remaining intact, or in the case of the sensitive D and I relay arrangement described in United States Patent No. 2,350,652, being rendered insensitive during the application of each pulse to line. As regards resistance YW this serves slowly to drain away any residual charge on condenser QJ when the outgoing repeater is subsequently released at the end of the call.

At the distant receiving end, shown in Fig. 25, relay 2A operates on seizure of the relay set by the forward extension of the direct current loop but it will be noted that relay 2B need not be slow-to-release since relay 2A is only adapted to respond to the direct current supervisory and holding signals and does not do so to the subsequently received alternating current impulses. The latter are adapted to be received on a rectifying unit RU which might consist of a dry plate rectifier bridge followed by a small gas discharge tube in the anode circuit of which relay 2PU would be situated. As more fully described in United States application Ser. No. 446,900, this gas discharge tube would be caused to flash on the incremental front or on the decremental termination of each signal wave and would remain locked in until relay 2PU had at contacts *2pu1* repeated a suitable "flick" direct current pulse out over the negative wire to the associated incoming control relay set which actually forms a part of the incoming relay set and which precedes the selector train, contacts *h4* and *f1* being contacts of the control set relays H and F.

As soon as the control group has steered the call to the wanted subscriber the H relay therein will be operated if this subscriber is found to be free, while the G relay will be operated if he is engaged as described in connection with the control relay set of Fig. 22. In either case the rectifying unit is disconnected by additional contacts *h* or *g* of these relays from across the lines in readiness for speech or tone transmission.

In the case of a tandem exchange an incoming selector will conveniently be similar to that shown in Fig. 23 except that the dotted rectangle

will in this case represent a control relay set combining the A. C. receiving arrangement RU of Fig. 25 and the normal functions of the control group of Fig. 22.

The received alternating current impulses will be converted to direct current "flick" impulses to actuate the tandem selector train via the control relay set, while relay OG will be operated as described in connection with Fig. 23 to disconnect the modified control relay set when a tandem outgoing repeater is taken into use. Subsequent alternating current impulses will thereupon extend through to the outgoing repeater such as shown in Fig. 24, and will pass through the Stone bridge therein comprising relay IA, the D and I relays and condensers QU and QH with their respective contact setting resistances YT and YV to the distant incoming relay set at the required exchange or at another tandem exchange in the same manner as for speech.

Several points should be noted about this arrangement:

1. No attempt has been made to preserve any impulse ratio. The pulse is merely a kick which triggers the later operations of the selector, and no regard is paid to the impulse break and make ratio determined by the subscriber dial. The only use made of the dialled impulses is that they serve to indicate the number of impulses in a train. This arises from a combination of self-correcting magnets and speed timing.

2. No difficulty is encountered with speech condensers and moreover the impulse receiving shunt is removed before either tones or speech is required. This arises from the position of the bridge preceding the first selector.

3. The system combines easily with the long distance voice frequency systems. When it is desired to work over a 2 V. F. or some other all A. C. system, arrangements are provided in association with lines outgoing from the area to transform the seizing and supervisory signals into the appropriate A. C. equivalents. The dialling and actuating pulses are sent out unchanged.

The advantages of the new invention are set out below. The ratchet and pawl, hammer drive of the decimal step-by-step selector has been replaced by a very smooth drive. Not only have all the violet accelerations and sudden stops been removed but also the sharp edge driving pawls, jamming operation and the like. The performance of this selector should in the matter of wear be immeasurably superior to its predecessors. This point would be greatly assisted by the increased bank tolerances, the primary movement has been doubled, the secondary control margin greatly increased. Hence a greater amount of variations can be allowed before things begin to fail. The directness of the mechanism should be noted. All mechanical springs are operated without the use of levers. This fact again increases the possible tolerances. Ample power is available and it is no longer necessary to work as near to predetermined limits as hitherto in order to get a desired performance.

With regard to talking efficiency which is the thing the subscriber is essentially interested in, all bank contacts are made of silver instead of base metals. Ample pressures and dual contacts are provided. These contacts moreover are self-aligning and cannot shift with regard to each other and so cause microphonic noises. The circuits also have been so designed as to reduce the contacts in the speech path to a minimum. In a normal 10,000 line exchange there are about 24 contacts points in the talking circuit neglecting the preselector or finder stage. In the proposed system this number is reduced to 10.

I claim:

1. In an automatic switching system, a line, a switch associated with said line, means for transmitting electrical impulses over said line to said switch, a movable member in said switch, a continuously operating source of mechanical power, means in said switch for receiving said impulses and, under the control thereof, causing said source to operate said member step by step in each of two directions parallel to the same plane, means for then operating said member in a direction transverse to said plane, and a line outgoing from said switch connected to said first line responsive to said last operation of said member.

2. In a switching system, an automatic switch having an incoming line, an outgoing line, a movable contact making member, and a rotating driver; means for transmitting electrical impulses over said incoming line to said switch; transfer means in said switch between said driver and said member controlled by said impulses over said incoming line for causing said driver to move said member step by step in each of two directions substantially in a plane perpendicular to the axis of rotation of said driver; said contact making member effective after it has been moved in said two directions to complete an electrical circuit between said incoming line and said outgoing line.

3. In an automatic switch, an incoming line, an outgoing line, a movable contact making member, a rotating driver, transfer means between said driver and said member controlled over said incoming line for causing said driver to move said member step by step in each of two directions substantially in a plane perpendicular to the axis of rotation of said driver, means operated after said contact making member has been moved in said two directions for then moving it in a direction perpendicular to said plane, and an electrical connection between said incoming line and said outgoing line completed responsive to said last movement of said contact making member.

4. In a switching system, a plurality of groups of elongated primary conductors, all of said conductors being parallel and each group thereof occupying a plane parallel to the planes occupied by the other groups, a plurality of groups of secondary conductors, each of said secondary conductors being transverse to the length of said primary conductors and each group of secondary conductors being substantially in a plane parallel and adjacent to the plane occupied by a particular group of primary conductors, a control unit, means for transmitting electrical impulses to said unit, a contact-making member in said unit controlled by said impulses to move in one direction to select a particular secondary conductor and to move in a different direction to select a particular primary conductor, said member effective, after it has been moved in both of said directions, to complete an electrical circuit between the selected primary and secondary conductors.

5. In an automatic switch, a plurality of independently operable contact sets each having a movable part and a stationary part, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line being connected to one of the parts of its corresponding contact set, an incoming line

permanently connected in multiple to the other part of every said contact set, whereby said incoming line may be connected to any one of said outgoing lines by moving the movable part of the contact set corresponding to said one outgoing line into engagement with the stationary part of that contact set, a control circuit connected to said incoming line, and mechanism controlled directively by said circuit over said incoming line for selecting any desired one of said contact sets and moving the movable part thereof into engagement with the associated stationary part.

6. In an automatic switching system, a plurality of independently operable contact sets each having a movable part and a stationary part, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line being connected to one of the parts of its corresponding contact set, an incoming line permanently connected in multiple to the other part of every said contact set, whereby said incoming line may be connected to any one of said outgoing lines by moving the movable part of the contact set corresponding to said one outgoing line into engagement with the stationary part of that contact set, contact controlling mechanism, means for impressing electrical impulses upon said incoming line, circuit means for receiving said impulses and operating said mechanism step by step under control thereof to select different ones of said contact sets at different times, and means in said mechanism operated at each of said times for moving the movable part of the selected contact set into engagement with the associated stationary part.

7. In an automatic switch, a plurality of groups of independently operable contact sets, each contact set having a movable part and a stationary part, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line being connected to one of the parts of its corresponding contact set, an incoming line permanently connected in multiple to the other part of every said contact set, whereby said incoming line may be connected to any one of said outgoing lines by moving the movable part of the contact set corresponding to said one outgoing line into engagement with the stationary part of that contact set, contact controlling mechanism, circuit means for operating said mechanism step by step under control of electrical impulses received over said incoming line to select different ones of said groups at different times, and means effective after a group has been selected for then operating said mechanism to select a particular contact set in the selected group and to move the movable part of the selected contact set into engagement with the associated stationary part.

8. In an automatic switch, a contact bank including a plurality of independently operable contact sets each having a movable part and a stationary part, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line being connected to one of the parts of its corresponding contact set, an incoming line connected in multiple to the other part of every said contact set, whereby said incoming line may be connected to any one of said outgoing lines by moving the movable part of the contact set corresponding to said one outgoing line into engagement with the stationary part of that contact set, a contact operating unit, means including a jack for detachably mounting said unit in operative relationship to said contact bank, circuit means in said unit connected to said incoming line via said jack whenever said unit is thus mounted, and mechanism in said unit controlled by said circuit means over said incoming line to select any particular one of said contact sets and move the movable part thereof into engagement with the associated stationary part.

9. In an automatic switching system, a plurality of groups of contact sets, each contact set having two parts which normally are not in electrical connection with one another, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line connected to one part of its corresponding contact set, an incoming line permanently connected in multiple to the other part of every contact set, means for impressing electrical impulses upon said incoming line, contact controlling mechanism, circuit means for receiving said impulses and operating said mechanism step by step in a particular direction under control thereof to select a particular one of said groups, other circuit means effective after a particular group has been selected for then operating said mechanism in a different direction to select a particular contact set in the selected group, and circuit means then operative to cause said mechanism to complete an electrical connection between the two said parts of said selected contact set.

10. In an automatic switch, a contact bank including a plurality of groups of contact sets, each contact set having two parts which normally are not in electrical connection with one another, a plurality of outgoing lines corresponding respectively to the different ones of said contact sets, each outgoing line connected to one part of its corresponding contact set, an incoming line connected in multiple to the other part of every contact set, a contact controlling unit including selective mechanism, means including a jack for detachably mounting said unit in operative relationship to said contact bank, circuit means in said unit connected to said incoming line via said jack when said unit is thus mounted, said circuit means controlled over said incoming line to operate said mechanism in one direction to select any particular one of said groups and then to operate it in a different direction to select any contact set in the selected group, and means controlled by said unit after a particular contact set has been selected for completing an electrical connection between the two said parts of that contact set.

11. In a switching system, an incoming line, a plurality of outgoing lines, a bank of contacts operable to connect said incoming line to any of said outgoing lines, a switch mechanism, means including a jack for detachably mounting said mechanism in operative relationship to said bank, apparatus in said mechanism connected to said incoming line via said jack when said mechanism is thus mounted, said apparatus controlled over said incoming line at times to cause said mechanism to select any one of said outgoing lines, and means in said mechanism for then operating certain contacts in said bank thereby to complete a connection from said incoming line to the selected outgoing line independently of said jack.

12. In a switching system, an incoming line, a plurality of outgoing lines, a bank of contacts operable to connect said incoming line to any of said outgoing lines, a switch mechanism, means

including a jack for detachably mounting said mechanism in operative relationship to said bank, apparatus in said mechanism connected to said incoming line via said jack when said mechanism is thus mounted, said apparatus controlled over said incoming line to operate said mechanism step by step to select any one of said outgoing lines, means in said mechanism whereby it executes each step in the course of such selection without sudden changes in acceleration or deceleration, and other means in said mechanism operated after an outgoing line has been selected to cause certain contacts in said bank to complete a connection from said incoming line to the selected outgoing line independently of said jack.

13. In a switching system, an incoming line, a plurality of outgoing lines, a bank of contacts operable to connect said incoming line to any of said outgoing lines, a shaft rotating about an axis which is fixed with respect to said bank, a switch mechanism, means including a jack for detachably mounting said mechanism in operative relationship to said bank and said shaft, means in said mechanism connected to said incoming line via said jack when said mechanism is thus mounted, said last means controlled over said incoming line at times to cause said rotating shaft to drive said mechanism to select any one of said outgoing lines, and means in said mechanism for then operating certain contacts in said bank thereby to complete a connection from said incoming line to the selected outgoing line independently of said jack.

14. A switching system as claimed in claim 13, wherein said last means causes said rotating shaft to drive said mechanism step by step to select said one outgoing line.

15. In a switching system, a plurality of incoming lines, a plurality of outgoing lines, a bank of contacts operable to connect any incoming line to any outgoing line, said bank including different groups of contacts for the different incoming lines, a plurality of switch mechanisms corresponding respectively to said different groups, means including a jack for detachably mounting each of said mechanisms in operative relationship to its corresponding group of said contacts, means in each mechanism connected via said jack to the incoming line for the group of contacts corresponding to that mechanism whenever said mechanism is thus mounted, said last means controlled over its connected incoming line at times to cause the associated mechanism to select any one of said outgoing lines, and means in said mechanism for then operating certain contacts of said group corresponding to that mechanism thereby to complete a connection independently of said jack from the incoming line for that group to the selected outgoing line.

16. In a switching system, an incoming line, a plurality of outgoing lines, a control unit, a jack via which all electrical connections between said incoming line and said unit are completed, means for transmitting electrical impulses over said incoming line and said jack to said unit, means in said unit controlled in accordance with said impulses to select a particular one of said outgoing lines, and means then controlled by said unit for completing an electrical connection between said incoming line and the selected outgoing line independently of said jack.

17. In a switching system, an incoming line, a plurality of outgoing lines, a control unit, a jack via which all electrical connections between said incoming line and said unit are completed, means in said unit operated directively over said incoming line and said jack to select any particular one of said outgoing lines, and means then controlled by said unit for completing an electrical connection between said incoming line and the selected outgoing line independently of said jack.

18. A switching system as claimed in claim 17, wherein said first means includes a movable member, electromagnets, and transfer means operated mechanically by said electromagnets to cause said member to move in steps, and wherein each of said electromagnets also operates certain circuit-controlling contacts.

19. In a switching system, an incoming line, a plurality of outgoing lines, a control unit, a jack via which all electrical connections between said incoming line and said unit are completed, mechanism in said unit controlled over said incoming line and said jack to execute a primary movement in one direction and a secondary movement in a different direction thereby to select a particular one of said outgoing lines, and means controlled by said unit when a particular outgoing line has been selected for completing an electrical connection between said incoming line and the selected outgoing line independently of said jack.

20. In a switching system, an incoming line, a plurality of outgoing lines, a control unit, a jack via which all electrical connections between said incoming line and said unit are completed, a continuously operating source of mechanical power, means in said unit controlled over said incoming line and operated step by step by said source to select any particular one of said outgoing lines, and means then controlled by said unit for completing an electrical connection between said incoming line and the selected outgoing line independently of said jack.

21. In a switching system, an incoming line, a plurality of outgoing lines, a control unit, a jack via which all electrical connections between said incoming line and said unit are completed, means in said unit operated directively over said incoming line and said jack to select any particular one of said outgoing lines, means then controlled by said unit for completing an electrical connection between said incoming line and the selected outgoing line independently of said jack, said last means including not to exceed one mechanically operable contact in any conductor of the completed connection.

22. In a switch for a telephone or like system, an incoming line and a plurality of outgoing lines, a continuously operating source of mechanical power, means controlled over said incoming line and operated step by step by said source to select any particular one of said outgoing lines, means then operated to complete a conversational connection between said incoming line and said outgoing line, said last means including not to exceed one mechanically operable circuit-making contact in any conductor of said conversational connection.

23. A switch as claimed in claim 22, wherein said one contact is a precious metal contact, whereby no base metal contacts are present in said conversational connection.

24. In a telephone system, a plurality of switches each having an individual incoming line, a plurality of outgoing lines common to said switches, a continuously operating source of mechanical power common to said switches, means individual to each switch at times controlled over

the incoming line for that switch and operated step by step by said source for causing that switch to select a particular one of said outgoing lines, a conversational connection then completed by said switch between the incoming line for that switch and the selected outgoing line, said conversational connection including not to exceed one contact closed by said switch in any conductor of said connection.

25. In a telephone system having a plurality of subsribers' lines, a battery feed common to said lines, means progressively advancing a connection from said battery feed through a plurality of switching stages to any one of said lines, said means including switching apparatus at each stage selectively controlled over said connection when the connection has been completed to that stage for further advancing the connection to the next stage, and not more than one electromagnetically operated contact per conductor at each stage in the completed connection through that stage.

26. In a telephone system having a plurality of subscribers' lines, a battery feed common to said lines, means for progressively advancing a connection from said battery feed through a plurality of switching stages to any one of said lines, said means including control means at the battery feed stage, switching apparatus at each succeeding stage selectively operated by said control means over said connection when the connection has been completed to that stage for further advancing the connection to the next stage, and not more than one electromagnetically operated contact per conductor at each of said succeeding stages in the completed connection through that stage.

27. In a switching system having a plurality of direct current loads, a source of direct current common to said loads, means for completing a two-conductor direct current circuit from said source over a plurality of successive switching stages to any one of said loads, said means including selective switching apparatus at each stage controlled over the circuit when same has been extended to that stage for advancing said circuit to the next switching stage, and not more than one mechanically operable contact per conductor at each stage in the completed circuit through that stage.

28. In an automatic switch, a plurality of independently operable contact sets arranged in parallel rows, each of said contact sets having a movable part and a stationary part, a plurality of primary lines corresponding respectively to the different ones of said contact sets, each primary line being connected to one of the parts of its corresponding contact set, a secondary line connected in multiple to the other part of every said contact set, whereby said secondary line may be connected to any one of said primary lines by moving the movable part of the contact set corresponding to said one primary line into engagement with the stationary part of that contact set, a movable member common to all of said contact sets, means for receiving impulses over said secondary line and, in accordance therewith, moving said member in a direction transverse to said rows to a position adjacent the end of a particular one of said rows, means for then moving said member parallel to said particular row to a position adjacent any particular one of the contact sets in that row, and means for then moving said member into engagement with the movable part of said particular contact set thereby to displace said movable part into engagement with the associated stationary part of such contact set.

29. In an automatic switch, a plurality of independently operable contact sets each having a movable part and a stationary part, a plurality of primary lines corresponding respectively to the different ones of said contact sets, each primary line being connected to one of the parts of its corresponding contact set, a secondary line connected in multiple to the other part of every said contact set, whereby said secondary line may be connected to any one of said primary lines by moving the movable part of the contact set corresponding to said one primary line into engagement with the stationary part of that contact set, a movable member common to all of said contact sets, a continuously operating source of mechanical power, means for receiving impulses over said secondary line, transfer mechanism controlled by said last means for causing said source to move said member in accordance with the received impulses to a position adjacent a particular one of said contact sets, and means for then operating said member to apply a force to the movable part of said particular contact set thereby to cause it to engage the associated stationary part.

30. In an automatic switch, a plurality of independently operable contact sets arranged in parallel rows, each of said contact sets having a movable part and a stationary part, a plurality of primary lines corresponding respectively to the different ones of said contact sets, each primary line being connected to one of the parts of its corresponding contact set, a secondary line connected in multiple to the other part of every said contact set, whereby said secondary line may be connected to any one of said primary lines by moving the movable part of the contact set corresponding to said one primary line into engagement with the stationary part of that contact set, a movable member common to all of said contact sets, a continuously operating source of mechanical power, means for receiving impulses over said secondary line, transfer mechanism controlled in accordance with the received impulses for causing said source to move said member in a direction transverse to said rows to a position adjacent the end of a particular one of said rows, impulse operated transfer means for then causing said source to move said member parallel to said particular row to a position adjacent any particular one of the contact sets in that row, and means for then operating said member to apply a force to the movable part of said particular contact set thereby to cause it to engage the associated stationary part of such contact set.

31. In an automatic switch, a contact bank including a plurality of independently operable contact sets each having a movable part and a stationary part, a plurality of primary lines corresponding respectively to the different ones of said contact sets, each primary line being connected to one of the parts of its corresponding contact set, a secondary line connected in multiple to the other part of every said contact set, whereby said secondary line may be connected to any one of said primary lines by moving the movable part of the contact set corresponding to said one primary line into engagement with the stationary part of that contact set, a contact operating unit having a movable member, means including a jack for detachably mounting said unit in operative relationship to said contact bank, a circuit

completed from said secondary line to said unit via said jack whenever said unit is thus mounted, means in said unit for receiving impulses over said circuit and moving said member in accordance therewith to a position adjacent a particular one of said contact sets, and means in said unit for then operating said member to apply a force to the movable part of said particular contact set thereby to cause it to engage the associated stationary part of such contact set.

32. In an automatic switch, a contact bank including a plurality of independently operable contact sets arranged in parallel rows, each of said contact sets having a movable part and a stationary part, a plurality of primary lines corresponding respectively to the different ones of said contact sets, each primary line being connected to one of the parts of its corresponding contact set, a secondary line connected in multiple to the other part of every said contact set, whereby said secondary line may be connected to any one of said primary lines by moving the

movable part of the contact set corresponding to said one primary line into engagement with the stationary part of that contact set, a contact operating unit having a movable member, means including a jack for detachably mounting said unit in operative relationship to said contact bank, a circuit completed from said secondary line to said unit via said jack whenever said unit is thus mounted, means in said unit for receiving impulses over said circuit and, in accordance therewith, moving said member in a direction transverse to said rows to a position adjacent the end of a particular one of said rows, means in said unit for then moving said member parallel to said particular row to a position adjacent any particular one of the contact sets in that row, and means in said unit for then operating said member to apply a force to the movable part of said particular contact set thereby to cause it to engage the associated stationary part of such contact set.

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