THE AUTOMATIC TELEPHONE EXCHANGE.

AT an ordinary or manual telephone exchange, as is generally known, the subscribers' lines terminate on "jacks," and are put through to each other by means of "plugs" and flexible conductors. The jacks, mounted on a suitable surface, form a "switchboard," and it is the business of the exchange operator to make the necessary connections and to sever them at the proper time, to answer calling subscribers and to ring up wanted ones. Large modern exchanges are worked on the common-battery plan; that is, no batteries whatever are placed at the subscribers' offices, but a large single battery is installed at the exchange, and this supplies all the current for speaking and signalling. The switchboard is of the "multiple" type. All the subscribers are brought to each division or section of the complete board; that is, all the subscribers' jacks in the entire exchange are repeated or multipled at each section, the latter forming a kind of unit of area representing the maximum reach of an operator. Every subscriber is thus within the reach of every operator. A simple "busy" test is arranged, so that before making a connection it can instantly be seen whether the required subscriber is free or already engaged at some other section. This grouping of the jacks, or "multiple" proper, is used only for ringing up and connecting to wanted subscribers. In addition, each operator has a certain number of subscribers brought to other—"answering"—jacks, placed in her immediate vicinity, and it is on these that calls from subscribers are received. At the subscriber's end everything is arranged with a view to simplicity. The signalling is automatic; that is, the subscriber has simply to lift his receiver and the exchange is called automatically, and when the conversation is finished the replacing of the receiver upon its hook advises the operator that the connection is to be severed.

FIG. 1.—Subscriber's Telephone with calling arrangement.

For automatic exchange working we have to substitute mechanism for the exchange operator, and the place of the large common switchboard is taken by a number of small individual switches, one of which is allotted to each subscriber and is entirely under his control. The plan which we are about to outline is the Strowger system, as applied to a small exchange of less than a hundred subscribers and operated on the common-battery plan. Other excellent systems are in use, but it is thought that some degree of detail of one system will be more useful than the statement of the main principles of several.

Considering the subscriber's end first. In addition to the usual speaking apparatus, transmitter, receiver, &c., we have the selecting and calling mechanism, as the subscriber has to "get through" to his correspondent by his own unaided efforts. Fig. 1 illustrates a "table set." In the central portion the figures 1 to 0 are arranged in a circle, and over them is a movable disc, perforated near the edge so that the figures, which are fixed, are visible through the holes. Suppose subscriber No. 58 is required. The receiver is first removed from its hook. A finger is then inserted in the hole through which the figure 5 shows, and the disc turned in a clockwise direction until a stop bars the way. This turning of the disc winds up an inner spring. The finger is then withdrawn and the spring carries the disc back again. In its return journey it causes one of the lines of the loop to be earthed (momentarily) five times, and at the end of this series the other line is earthed once. The finger is then inserted in the hole over the 8 and the disc brought round again—again winding up the spring. Its release and return to normal earths the first line eight times and then the second line once, as before. As the exchange battery is permanently on the lines, this earthing causes impulses of current to be sent over them by way of certain apparatus, and the calling subscriber is now through to No. 58 line. When any subscriber's receiver is on its hook, a magneto bell, in series with a condenser, is across the two lines. The calling subscriber now depresses a push-button, which action again earths the first wire of his own loop and actuates a relay at the exchange, which applies the generator to the required line.

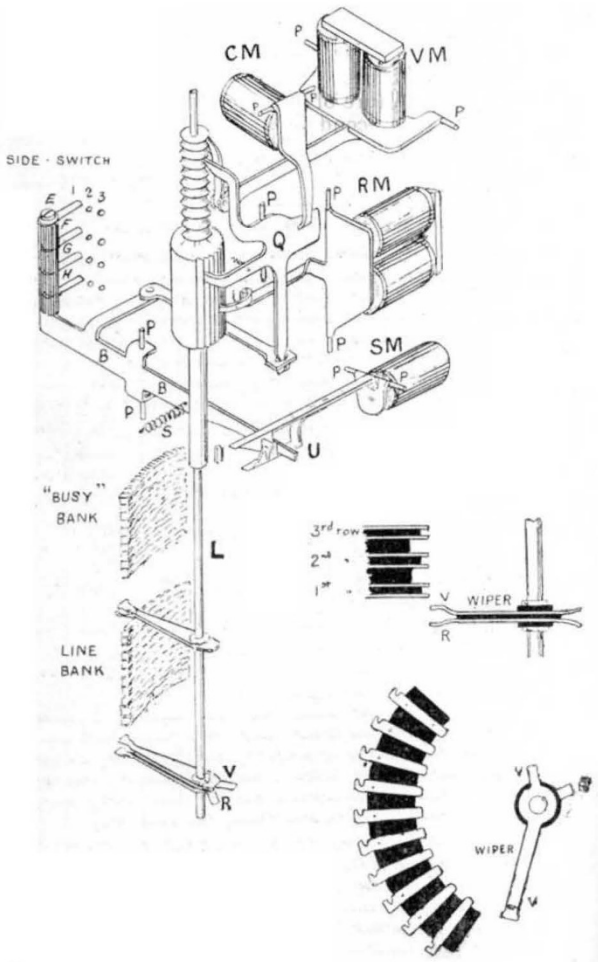

FIG 2.—Details of Subscriber's Switch at Exchange.

After conversation, both subscribers hang up their receivers, this action momentarily earthing both wires of each loop. In the case of the originating subscriber, the effect of this is to "clear," and to restore to normal his mechanism at the exchange.

At the exchange end of each loop a separate switch is placed, the mechanical outlines of which are given in Fig. 2 and the electrical connections in Fig. 3. Considering the former, we have an upright steel shaft L which has on its upper portion a series of horizontal teeth, cut the whole way round the shaft. VM is an electromagnet having a pawl on the end of its armature, the latter being pivoted at PP. When VM is energised, this pawl lifts the shaft by means of one of the horizontal teeth. Below these teeth the diameter of L is much increased, and on the surface of the cylinder thus formed, a series of vertical grooves or teeth are cut. RM is another electromagnet, the armature of which, pivoted at PP, carries at its extremity a second pawl. When this armature is attracted L is forced round a tooth. The double pawl Q engages with both the horizontal and vertical teeth, and prevents the return of the shaft after its movements in an upward and rotary direction. Each of these two electromagnets is placed, in turn, in the local circuit of a relay at the required time, and whenever an impulse passes through VM the shaft L is raised a tooth, whilst an impulse through RM causes the shaft to be rotated a tooth. They are therefore termed the "vertical" and "rotary" magnets. CM is the clearing magnet; when this is energised, its armature strikes the double pawl Q and causes it to release the shaft. The latter, in its previous turning movement, winds up a spring, and on its release the spring brings it back, and by its own weight the shaft falls to its normal position.

At the lower end of L two arms are carried which, when desired, make connection with any one of a series or "bank" of contacts. The essential parts of these contacts and of the arms are best seen in the right-hand lower corner of Fig. 2. First we have a thin semicircular strip of fibre or other insulating material. On the upper surface of this ten thin strips of metal are placed radially, and on the under surface ten other similar strips are placed. To an upper and a lower metal piece the lines of each loop are connected, so that one semicircular piece carries the twenty contacts of ten loops. Above this horizontal row of ten circuits a second, third, and tenth semicircular pieces are placed, each being separated from its upper and lower neighbours by further insulation. We have thus the contacts of a hundred loops arranged in ten layers of ten each.

As already seen, every subscriber has one of these switches, and the banks are all multipled together. That is, No. 58 line is brought to the fifty-eighth position on the banks of all the hundred switches constituting the exchange.

The two arms, or "wipers"—so called from their brushing or wiping action in passing over the contacts—each consist of two metallic strips, insulated from each other and from the shaft, the outer ends having a slight inward tendency, so that when they engage the two springs of a loop there is sufficient friction to ensure electric contact.

As will be seen from Fig. 2, there are two banks of contacts, one above the other, and two arms or wipers to engage with them. On the lower bank are the hundred loops as already detailed. The upper bank is employed for giving the "busy" signal. Its arm has the two contacts connected together, so that only a single connection is made in any one of the hundred positions. Like the lower bank, these are multipled on all the switches of the exchange. There are indeed, two multiples, the line multiple and the "busy," or "engaged," multiple. In the normal position of the shaft the wipers are just to the left of the banks and just beneath them. When L is raised one, two, &c., teeth, the wipers rise to the level of the first, second, &c., row. A single rotary movement then brings the wipers to the first loop in the row; two three, or more rotary movements bring the wipers to corresponding loops on that horizontal level.

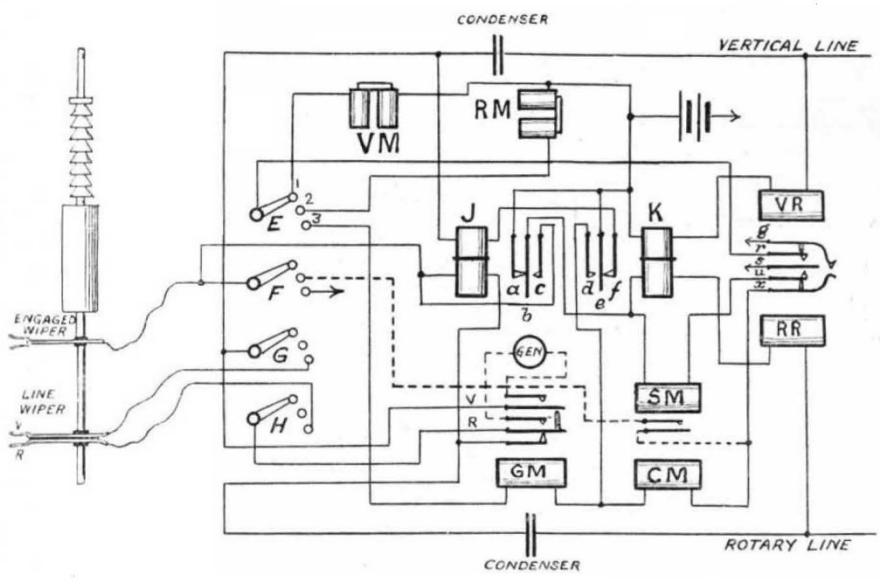

FIG. 3.—Subscriber's Switch—Connections.

Returning to the upper mechanism of the switch. BB is an arm pivoted at PP, and carrying on its left a four-lever switch. On its right it engages with the escapement U, which is carried on a long extension of the armature of the switch-magnet SM. A spring S keeps the right-hand end of BB against U. When SM is actuated, the movement of attraction and release allows BB to slip forward one step in the escapement, and causes E, F, G, and H to quit their first contact and move to the second. The action of this "side-switch" is to bring the various pieces of apparatus into action at the required time. A second movement of SM allows BB to move forward another step in U and brings the side-switch into the third position. Any further movement of SM does not affect BB. When, however, the clearing magnet CM is actuated, the movement of Q restores BB to its original position, the escapement springs opening and allowing the right-hand end to pass. The side-switch thus returns to position 1.

The electrical conditions are shown in Fig. 3. VM,

RM, CM, and SM are the electromagnets already described. VR and RR are the vertical and rotary relays, mounted side by side. The armatures of these when attracted act upon the contacts shown between them. If VR is energised, *g* is pressed forward together with *r*. The latter then makes contact with the centre spring *s*, but the movement is not sufficient to bring *g* and *x* together. When RR is actuated *x* is pressed forward, carrying *u* with it to make contact with *s*, but *x* does not reach *g*. When both relays are energised, *g* and *x* make contact in addition to the other two. Two other relays, J and K, are mounted together, and act upon the springs shown between them. Each of these two relays has two coils. If current circulates in one coil the armature responds: similarly if current flows in both coils in the same direction. If, however, the two currents are in opposite directions, they nullify each other's effects, and the armature is not attracted. The movement of J's armature breaks the contact between *b* and *a*, and makes a new one between *b* and *c*. Similarly with K: *e* breaks from *f* and makes with *d*. GM is the generator magnet. When this is actuated the two long springs move upwards, disconnecting from the lowest and bringing the generator on to the levers G and H of the side-switch, and thence (when in position 3) *via* the line wiper to the desired subscriber's line.

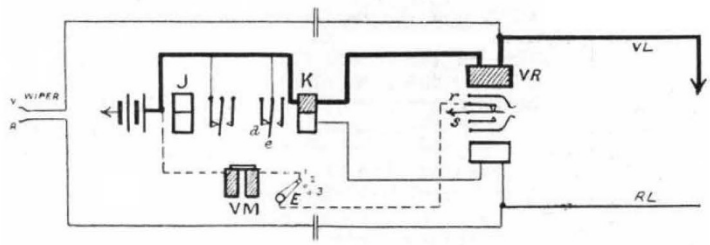

FIG. 4.—Earthing of Vertical Line.

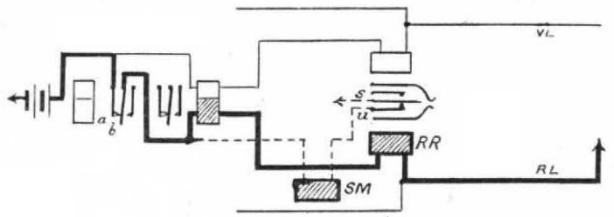

FIG. 5.—Earthing of Rotary Line.

We are now able to trace the results of the subscriber's call. He desired No. 58. By the first movement of his disc we saw that he earthed the vertical line five times and the rotary line once. Fig. 4 gives the result of this. By the earthing of the vertical line (as indicated by the arrow-head) a path, shown as a heavy line, is open to the battery from its positive pole through one coil of K and the vertical relay and line to earth. This current actuates both K and VR, as shown by the shading. The spring *r* being earthed at *s*, a second path, shown dotted, is open to the battery *via* VM and the lever E of the side-switch. The shaft L is therefore raised five teeth, corresponding to the number of current impulses passed over the vertical line. The earthing of the rotary line (once), as shown in Fig. 5 by the heavy line, actuates K by its lower coil and RR. The latter closes *s* and *u* and completes the circuit (shown dotted) of the switch magnet SM. This brings the side-switch into position 2.

The calling subscriber now inserts his finger in the eighth hole, brings the disc round, and then liberates it. The vertical line is then earthed eight times, and the rotary once. As the side-switch is in position 2 a circuit is open to the eight currents through the upper coil of K, VR, and the vertical line. K and VR are actuated, the latter connecting *r* and *s* and providing a second path from the battery through the rotary magnet, switch-lever E, and earth. The state of affairs is precisely as in Fig. 4, saving that RM is substituted for VM. The rotary magnet armature rotates the shaft (already on the level of the fifth row), and brings the wipers on to the eighth contact in that row. The final earthing of the rotary line repeats the operation shown in Fig. 5, and shifts BB another tooth in the escapement U, thus bringing the side-switch into position 3.

The wipers are now on the contacts of the desired loop and the calling subscriber depresses his push-

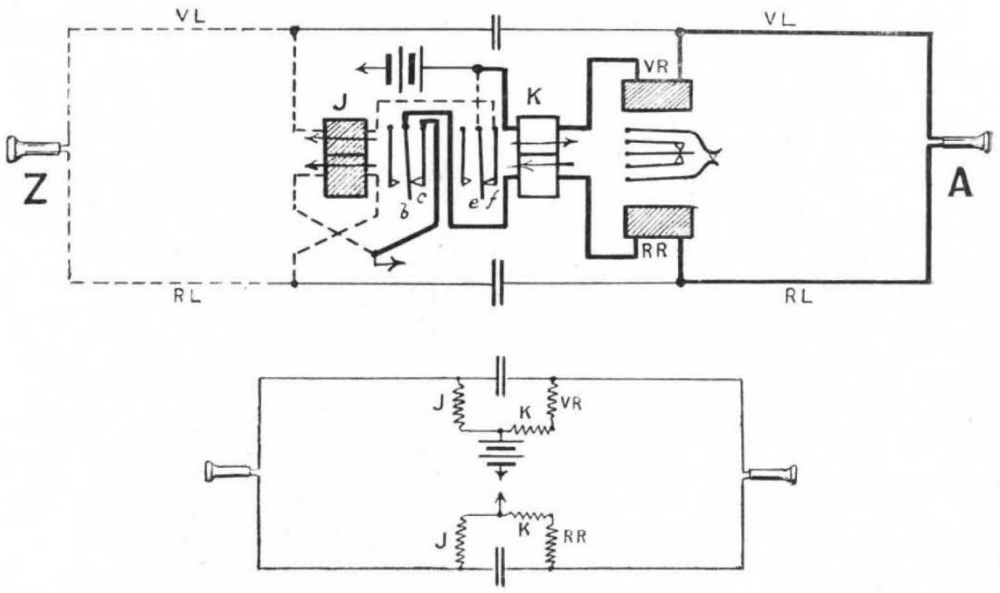

FIG. 6.—Two Subscribers "through."

button, which operation again earths the vertical line. VR is operated, and spring *r* making contact with *s* puts earth on the left-hand side of GM by way of switch-lever E (position 3). K also is operated by its upper coil, and the closing of its springs *e* and *d* brings the battery on the right-hand side of GM. The movement of GM's armature puts the generator (which is running continuously) on to the wipers, and thence to the required subscriber's (Z) loop, across which is placed his magneto bell, in series with a condenser. When Z replies, the current circulates through springs *e*, *f*, through the upper coil of J, round the loop, through J's lower coil, switch-lever F (position 3) to earth. J's two coils are now assisting each other, and spring *b* moves over to *c*. As *b* is joined to K's lower coil, this movement takes the battery from K's lower coil and puts on earth instead. The current now passes through K's upper coil, through VR, round A's loop, through RR and K's lower coil to earth *via c*. The currents in K, however, are opposing each other, so that the armature is not affected. The two subscribers are now "through," as in Fig. 6. The path traversed by the current on the left is shown by the dotted lines, and on the right by the heavy lines. The arrows through J and K show the direction through the separate coils, and the shading indicates the energised relays. The small skeleton diagram in Fig. 6 shows how the speaking circuit is made up. On Z's side the two coils

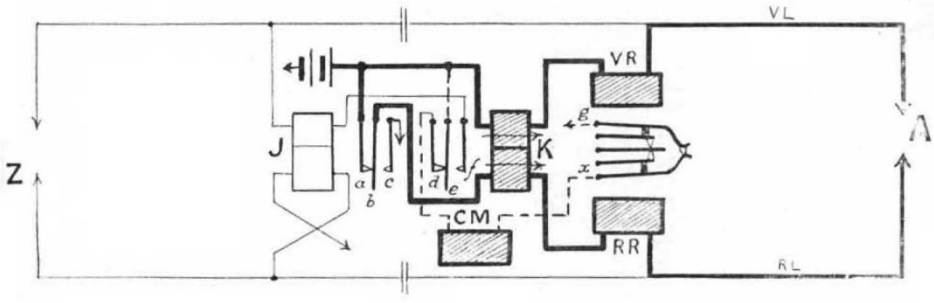

FIG. 7.—Clearing.

of J serve as impedance coils, whilst K's upper coil, plus VR and K's lower coil, plus RR, serve the same function on A's side.

On the conclusion of the conversation both subscribers hang up their receivers. In its passage downwards the switch-hook (momentarily) earths both the vertical and rotary lines simultaneously. The result of this action on A's part is that his rotary line is earthed at both ends. RR and the lower coil of K are thus short-circuited. K is then actuated by his upper coil, and by the movement of *e* from *f* to *d* current is cut off from J, which, ceasing to be energised, allows its armature to fall back. This causes *b* to leave *c* and return to *a*, substituting the battery for earth on the lower coil of K. Current now passes through both coils of K in the same direction, and thus continues to energise K, whilst both VR and RR being actuated, their outer springs make contact with each other and put earth on the right of the coils of CM, the clearing magnet. The other side of CM being connected with the battery through *d e*, the clearing magnet is energised. This is shown in Fig. 7, where the dotted line indicates the circuit of CM. The shaft is thus restored to its normal position and the circuits are cleared.

When a second caller attempts to get through to another subscriber who is already engaged, the following action takes place. As shown in Fig. 6 the earth on the left hand of J's lower coil is made by the lever F of side-switch in its third position. This puts earth on the "engaged" wiper, and through it on to all Z's contacts in the busy multiple. The new caller turns his disc twice in the usual way, thus getting on to Z's contacts in the line multiple. His (the newcomer's) side-switch, however, is still in position 2, so that, although his line wiper is on the required contacts, the wiper itself is still isolated. The final current over his rotary line causes RR and SM to be actuated. A contact on the latter (shown only in Fig. 3) is closed. The battery is already connected to the left hand of the newcomer's clearing magnet by means of his springs *d* and *e*. The closing of the contact on SM put the right-hand side of CM through to the earthed busy bank by way of lever F (position 2) of his own side-switch. His clearing magnet thus acts and his lever L returns to zero. By another contact (not shown) the busy signal from the generator is given over the newcomer's line, advising him that the required subscriber is engaged.

From the foregoing brief sketch it is hoped that the principle of working may be seen: the actual arrangements in practice involve large modification and extension. As only a certain percentage of the switches are in use at the same time, it is easily seen that it is unnecessary to provide one for every subscriber. A much simpler piece of apparatus, the "line switch," is therefore substituted, and only a comparatively small number of switches proper provided. The function of the first is simply to put a calling subscriber through to a disengaged switch—now slightly modified and called a "selector"—by which a certain group is selected. The subscriber having got through to the required group, now utilises a second switch, arranged practically as we have described and termed a "connector," through which he obtains access to the required correspondent. A still larger exchange will require a first selector, a second, &c., selector, and finally a connector. Taking the common case of an exchange with a maximum of 9999 subscribers: the line switch puts the caller through to a first selector, by which the thousands digit is selected. The hundreds figure is then picked out by the second selector, and the tens and units by the vertical and rotary movements of the connector.

ARTHUR CROTCH.

THE SUMMER OF 1911.

THE summer of 1911 has been remarkable in so many ways that without doubt it will receive the special attention of meteorologists, and will in course of time be dealt with very thoroughly, as it well deserves to be. Having for many years past kept touch with the published Greenwich weather records, a comparison of the present summer with the observations of the past seventy years, from 1841, may be of interest from one not officially attached to the Royal Observatory.

The exceptional character of June, July, and August lead naturally to the supposition that the summer proper, as limited to the three months, would beat all previous records in many ways, and this impression is amply supported by weather statistics.

The summer six months, April to September, can also claim a record so far as temperature is concerned. The mean temperature for the six months is