Feb. 18, 1930. L. J. BOWNE ET AL 1,747,219

TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 1

FIG. 1.

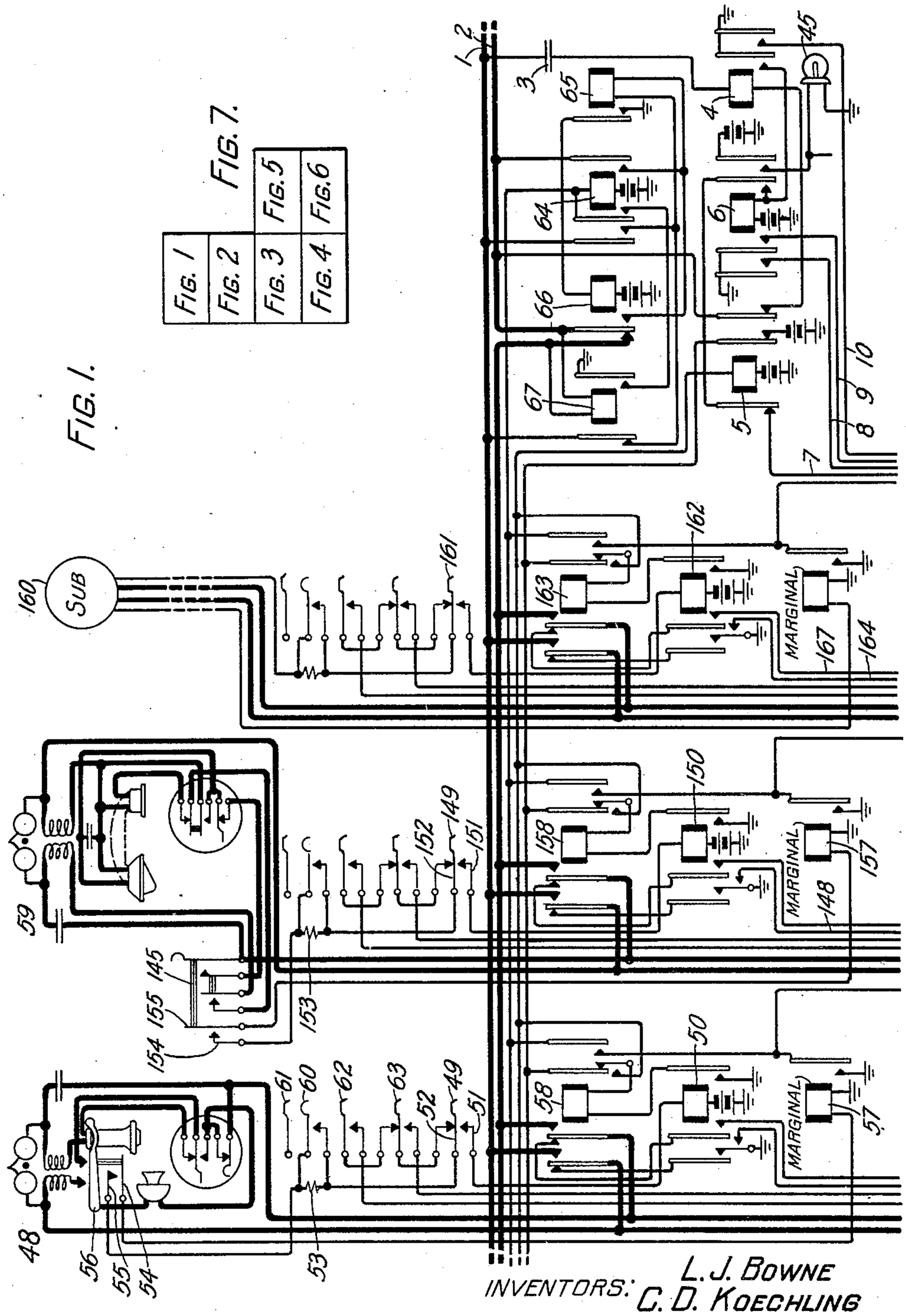

FIG. 7.

FIG. 1	FIG. 2	FIG. 3	FIG. 4
		FIG. 5	FIG. 6

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Feb. 18, 1930. L. J. BOWNE ET AL 1,747,219

TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 2

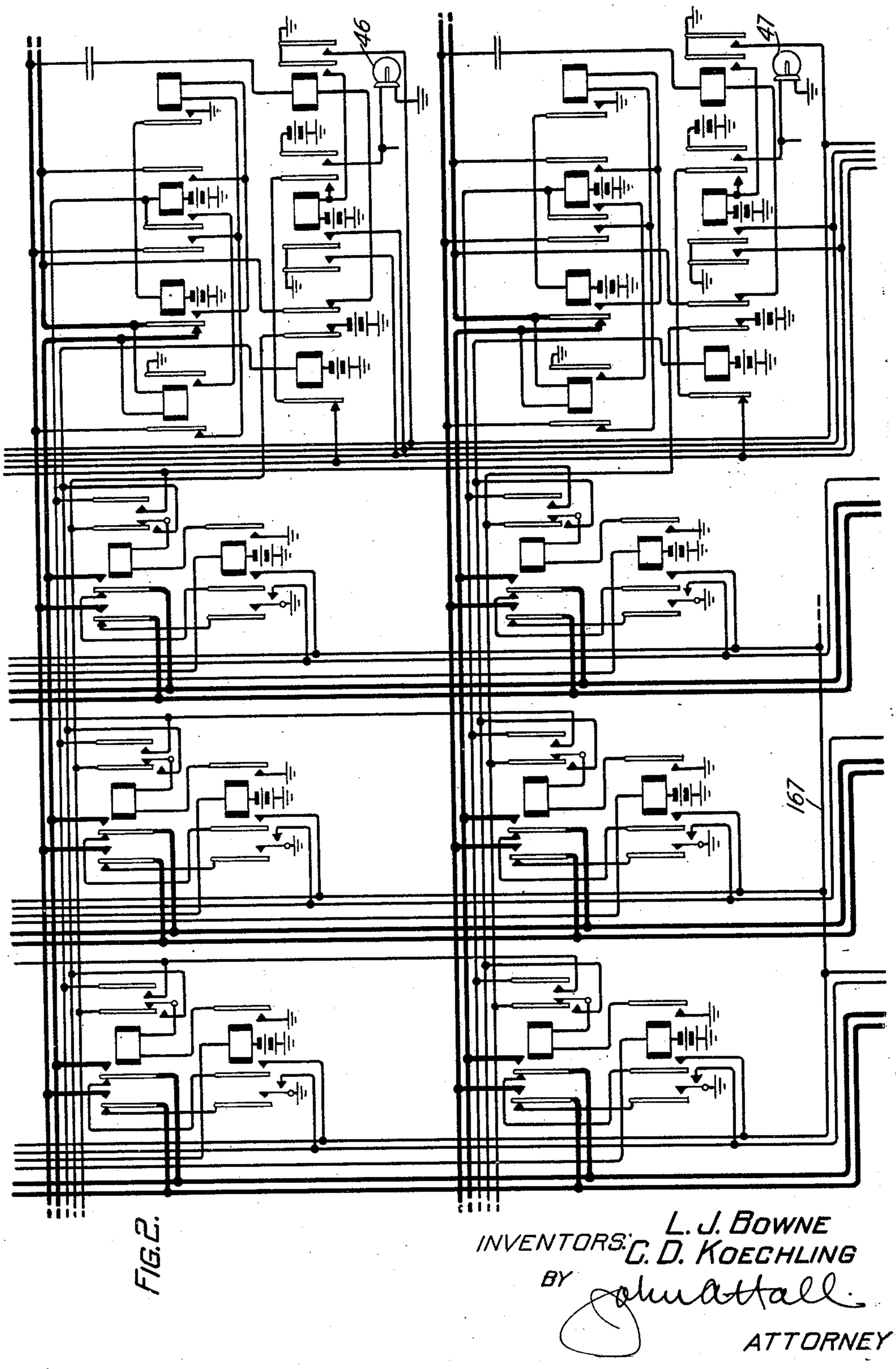

FIG. 2.

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Feb. 18, 1930. L. J. BOWNE ET AL 1,747,219

TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 3

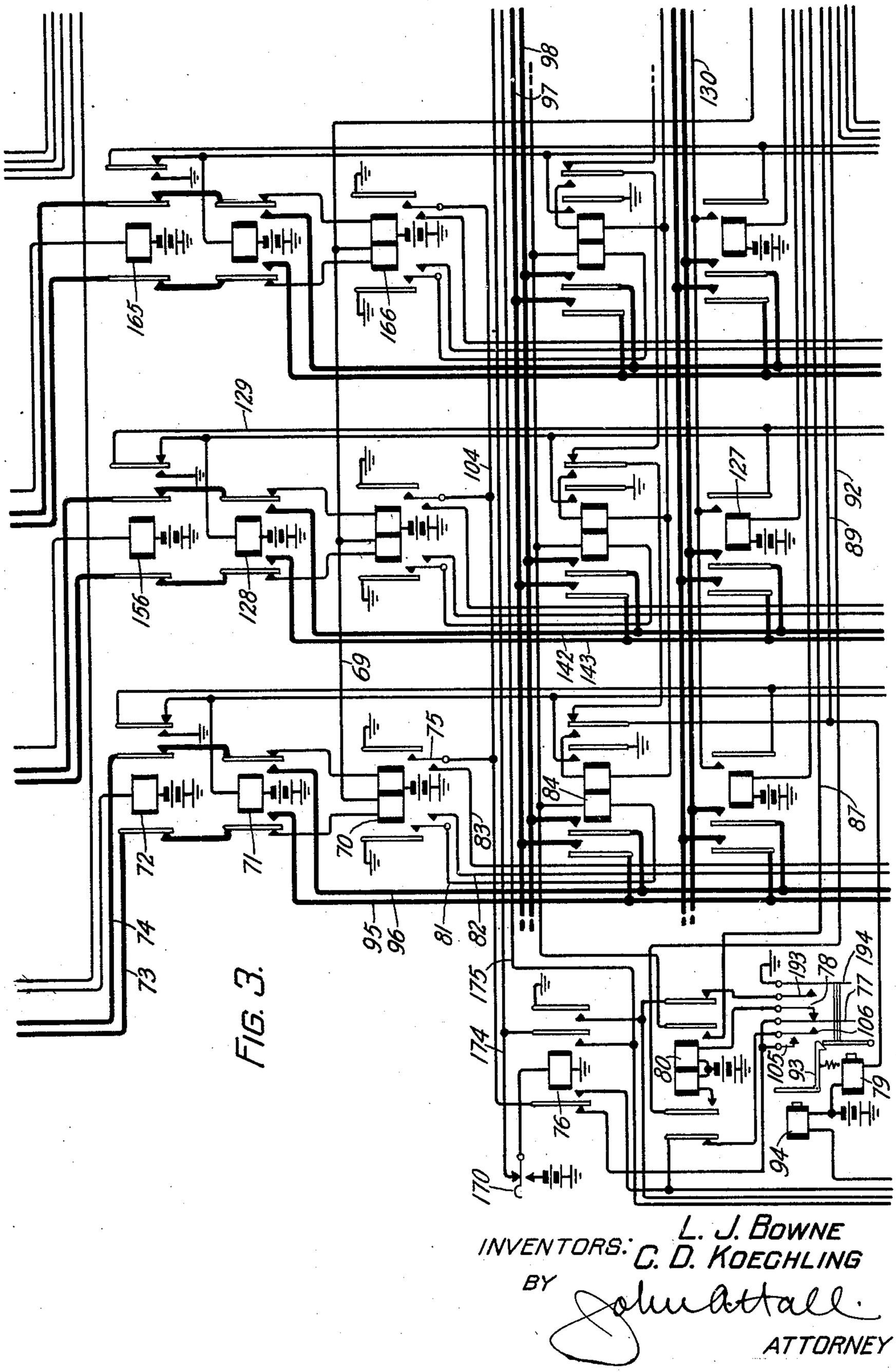

FIG. 3.

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Feb. 18, 1930. L. J. BOWNE ET AL 1,747,219

TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 4

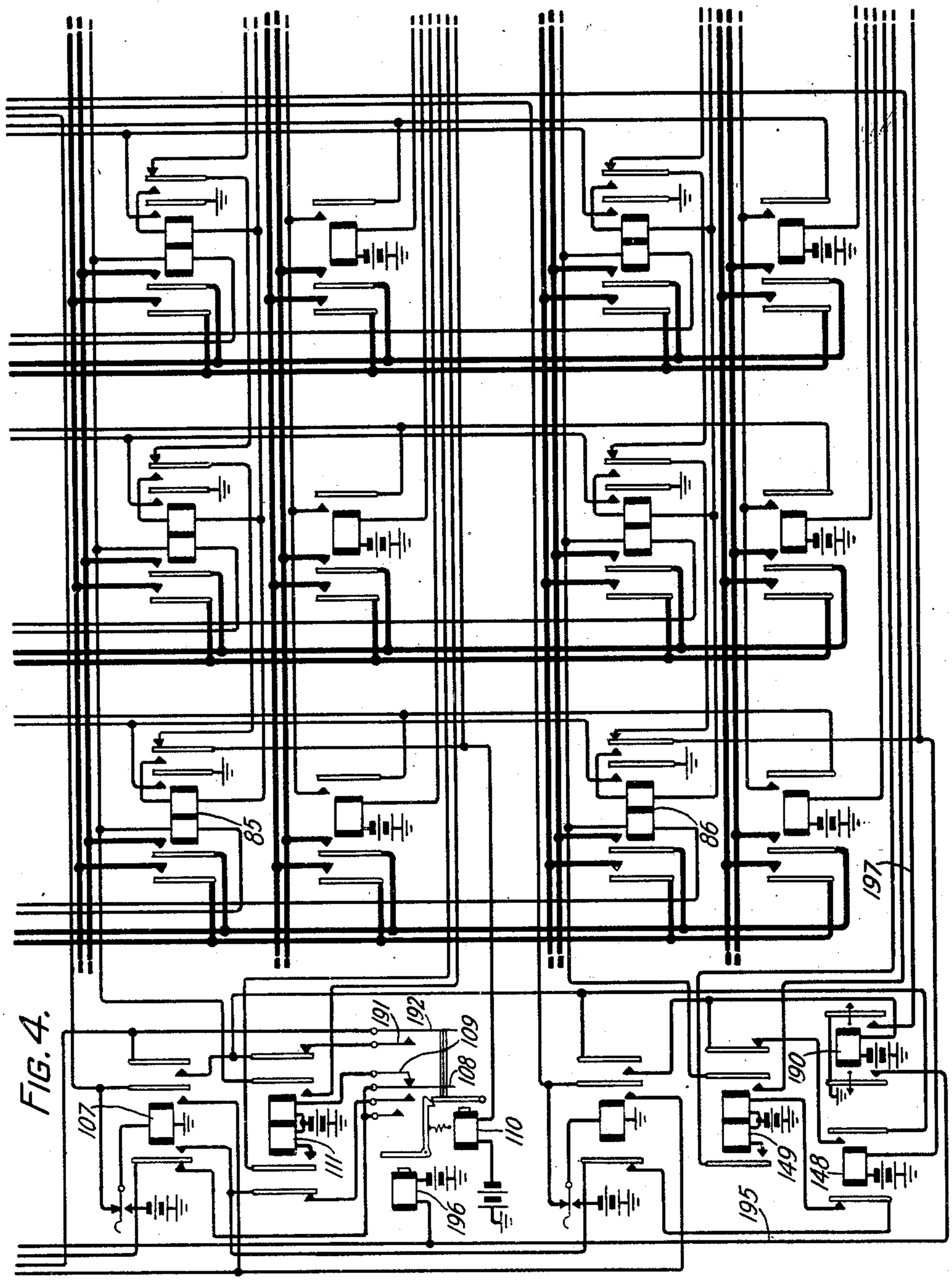

FIG. 4.

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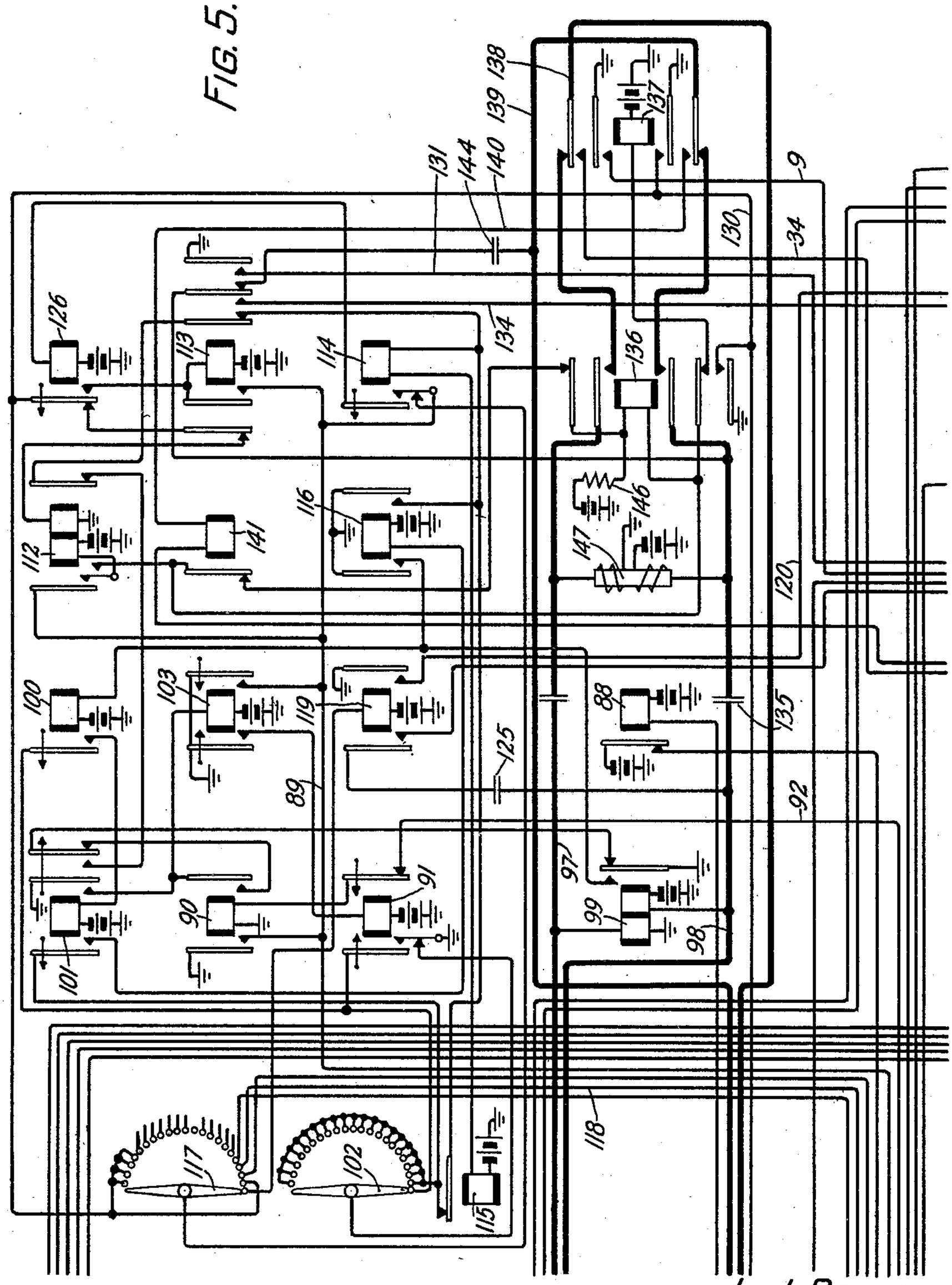
TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 5

FIG. 5.



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TELEPHONE SYSTEM

Filed March 14, 1929 6 Sheets-Sheet 6

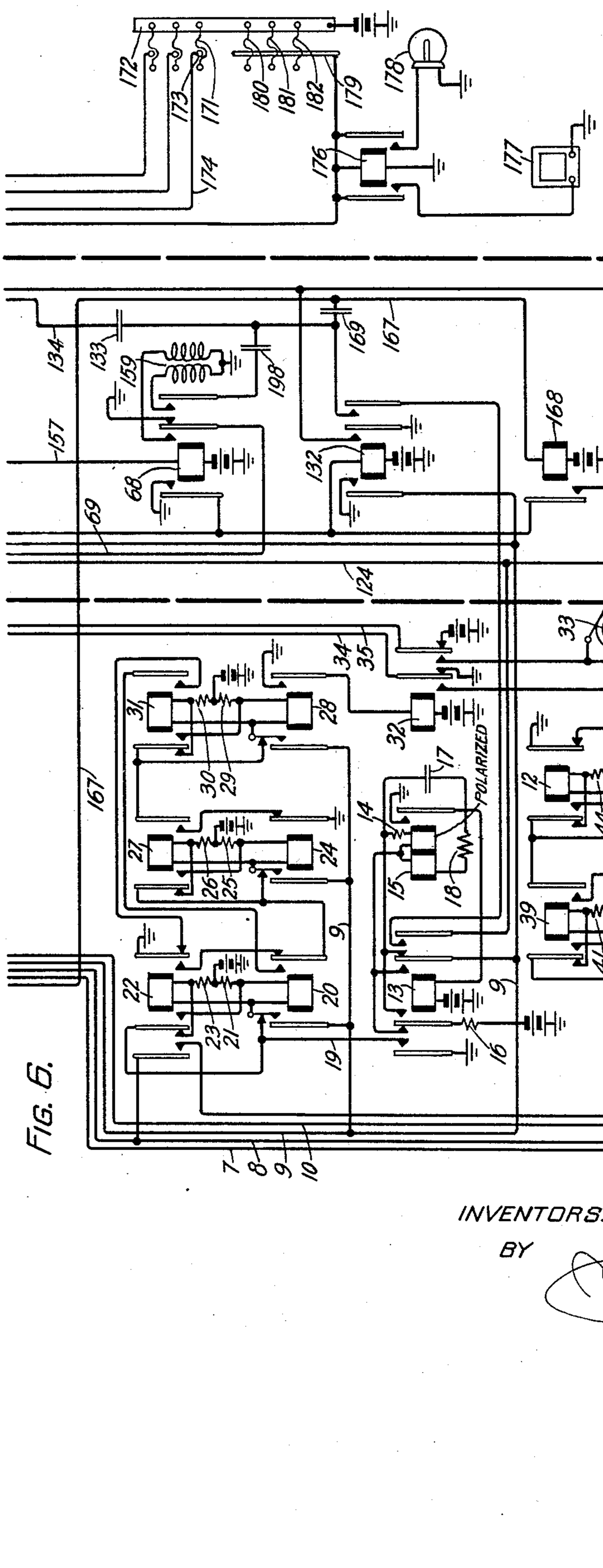

FIG. 6.

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Patented Feb. 18, 1930 1,747,219

UNITED STATES PATENT OFFICE

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TELEPHONE SYSTEM

Application filed March 14, 1929. Serial No. 346,826.

This invention relates to telephone systems and particularly to small capacity intercommunicating systems having central office service.

In accordance with one feature of the invention each line is provided with a connecting relay per trunk and a pair of connecting relays per link, one for incoming and the other for outgoing service. The line is also provided with a switching point which may be termed a line circuit and which comprises a line relay, a cut-off relay and a link cut-off relay. The line relay and the cut-off relay are well known in the art and are arranged to perform their usual functions but the link cut-off relay and its function is deemed to be new. The line from the substation enters first, the points of access to the trunks, second, the above named line circuit, and third, the points of access to the links and the link cut-off relay acts as a means to entirely disconnect the line from the local link circuits when a trunk connection is established. Looking at the line within the switching apparatus as consisting of two parts, first, the points of access to the trunks and, second, the points of access to the links, the link cut-off relay acts as a means to cut the line in two. Thus the line is severed from connection to all local apparatus during a trunk connection and the possibility of interference causing poor transmission by local means is minimized.

In accordance with another feature of this invention control of the trunk connecting relays is placed jointly in the switchhook and a plurality of individual trunk keys at each station.

Figs. 1 to 6, when placed as indicated in Fig. 7, diagrammatically illustrate the various circuits comprising a dial P. B. X. embodying the features of the present invention. Fig. 1 shows three substation lines and one trunk line leading to a central office, Fig. 2 shows two additional trunk lines leading to a central office, Fig. 3 shows a line circuit for each of the substation lines of Fig. 1 and the connecting relays for a first link circuit, Fig. 4 shows the connecting relays for two additional link circuits, Fig. 5 shows the operating relays for the link circuit of Fig. 3, and Fig. 6 shows various auxiliary circuits, such as the ringing and timing circuit at the left, the tone circuit within the two broken lines, and the alarm circuit to the right.

Let us first assume that a call is being made from the central office to the private branch exchange. The two conductors 1 and 2 lead from an ordinary subscriber's line circuit at a central office and under normal conditions would have ground and battery thereon through the windings of a line relay at the central office.

We will assume that a connection has been made to such line at the central office and that ringing current is being transmitted thereover from any well known source of ringing current under machine conditions. This presupposes a ringing interval of approximately two seconds and a silent interval of approximately four seconds. The incoming ringing current travels from conductor 1, through condenser 3, ringing relay 4, the back contact and outer right hand armature of relay 5, to conductor 2. Relay 4 is operated in this circuit and through its inner right hand armature and front contact causes the operation of relay 6.

With relays 4 and 6 operated, ground is placed on each of conductors 7, 8, 9 and 10. The ground on conductor 7 comes from the inner right hand armature and front contact of relay 4, through the front contact and inner right hand armature of relay 6, the left hand armature and back contact of relay 5. Ground on conductor 8 comes from the outer left hand armature and front contact of relay 6. Ground on conductor 9 comes from the inner left hand armature and front contact of relay 6 and ground on conductor 10 comes from the outer right hand armature and front contact of relay 4.

Conductors 7, 8, 9 and 10 may now be traced directly to Fig. 6 where it will be seen that the ground on conductor 10 energizes relay 11 and the ground on conductor 7 is met by another ground supplied over the right hand armature and back contact of relay 12. This ground maintains relay 6

energized when relay 4 becomes deenergized during a silent interval.

Ground on conductor 9 now passes through the inner right hand armature and back contact of relay 13 through resistance 14, right hand winding of relay 15, back contact and inner left hand armature of relay 13, resistance 16, to battery and ground. Another circuit is established from the ground on conductor 9, through the inner right hand armature and back contact of relay 13 to one terminal of condenser 17, the other terminal of which is connected through resistance 18, the left hand winding of relay 15, back contact and inner left hand armature of relay 13, resistance 16, to battery and ground. Thus, while relay 15 is being energized through its right hand winding, the condenser 17 is being charged through the left hand winding of relay 15.

The proper selection of the values of resistances 14, 16 and 18 and condenser 17, results in the slow operation of relay 15 whereby it is approximately one-half second before relay 15 becomes energized. At this time a circuit is established from ground, the front contact and armature of relay 15, winding of relay 13 to battery and ground. Relay 13 immediately energizes and through its inner right and left hand armatures reverses the current supply to relay 15 and condenser 17, whereby relay 15 which is polarized becomes deenergized, through the reversal of current in its right hand winding and the discharge of the condenser in its left hand winding. The release of relay 15 opens the circuit of relay 13 causing another reversal of current in the right hand winding of relay 15 and the condenser 17.

Thus, as long as ground is maintained on conductor 9, relays 13 and 15 will act and react so that ground is periodically connected to conductor 19 from the outer left hand armature and front contact of relay 13. Relays 13 and 15 and the connecting resistances and condenser 17 are so adjusted in their values that ground is periodically placed on conductor 19 for one-half second and taken off for one-half second, thus requiring a full second for a complete cycle of operations of relays 13 and 15.

In order to more clearly explain the following automatic action of the ringing and timing circuit, we shall speak of a series of periods as measured by the operation of relay 13. Thus, the first period will be a one-half second operation of relay 13, the second period will be a one-half second release of relay 13, the third period a one-half second operation of relay 13, etc.

At the beginning of the first period ground will be connected from conductor 19, through the alternate contacts of the left hand armature of relay 20, winding of relay 20, resistance 21, to battery and ground. Relay 20 will operate in this circuit and will lock through its left hand armature and alternate contact to the ground on conductor 9. The ground on conductor 19 will also be connected through the inner left hand armature and front contact of relay 22, to one terminal of relay 22 so that this relay is now short circuited and prevented from operating.

At the beginning of the second period, ground is removed from conductor 19 whereupon relay 22 becomes energized in a circuit from ground on conductor 9, the left hand armature and alternate contact of relay 20, winding of relay 22, resistance 23, to battery and ground. Relay 20 is maintained energized.

At the beginning of the third period, ground is again placed on conductor 19 whereupon relay 20 is short circuited through ground on conductor 19 being extended over the inner left hand armature and front contact of relay 22 to one terminal of relay 20. Relay 20 releases and the short circuit about its winding is maintained through the alternate contacts of the left hand armature of relay 20. At this same time a circuit is established from ground, the right hand armature and front contact of relay 22, the back contact and right hand armature of relay 20, the alternate contacts of the left hand armature of relay 24, resistance 25, to battery and ground. Relay 24 becomes operated and locks to the ground on the conductor 9 through its left hand armature and alternate contact. Relay 27 is short circuited through its left hand armature and back contact.

At the beginning of the fourth period, ground is removed from conductor 19 whereupon the circuit for relay 22 is opened and this relay becomes deenergized. At this time, due to the movement of the right hand armature of relay 22 the short circuit about the winding of relay 27 is removed and this relay now becomes energized in a circuit from ground on conductor 9, the left hand armature and alternate contact of relay 24, winding of relay 27, resistance 26, to battery and ground.

At the beginning of the fifth period, ground is again placed on conductor 19 whereupon relay 20 becomes energized as before. This, however, has no effect on either relay 24 or 27.

At the beginning of the sixth period, relay 22 becomes energized as before but this again has no effect on either relay 24 or 27.

At the beginning of the seventh period, ground is again placed on conductor 19 whereupon relay 20 becomes deenergized as before but now since relay 22 is energized a circuit is established from ground, the right hand armature and front contact of relay 22, the back contact and right hand armature of relay 20, the left hand armature and front contact of relay 27, resulting in the short circuit of relay 24, whereby this relay becomes

deenergized. At this time also a circuit is established from ground, the right hand armature and back contact of relay 24, the front contact and right hand armature of relay 27, the alternate contacts of the left hand armature of relay 28, resistance 29, to battery and ground resulting in the energization of relay 28. Relay 28 now locks through its left hand armature and normal contact to the ground on conductor 9, and relay 31 is short circuited through this ground and the ground on its left hand armature leading to its other terminal. The energization of relay 28 results in the energization of relay 32 so that relay 32 is first energized at the beginning of the seventh period.

At the beginning of the eighth period, ground is removed from conductor 19 whereby relay 22 is deenergized as before and relay 27 becomes deenergized as the result thereof. A circuit is now established from ground on conductor 9, through the left hand armature and alternate contact of relay 28, winding of relay 31, resistance 30, to battery and ground resulting in the operation of relay 31. Relay 28 is maintained energized.

At the beginning of the ninth period, ground is again placed on conductor 19 whereby relay 20 becomes operated as before. At this time a circuit is established from ground, right hand armature and back contact of relay 22, front contact and right hand armature of relay 31, back contact and right hand armature of relay 20, alternate contacts of the left hand armature of relay 24, to cause the operation of relay 24 as before.

At the beginning of the tenth period, relay 22 becomes operated thus opening the original energizing circuit of relay 24 and resulting in the energization of relay 27.

At the beginning of the eleventh period, relay 20 becomes deenergized whereupon a circuit is established from ground, the right hand armature and front contact of relay 22, the back contact and right hand armature of relay 20, the left hand armature and front contact of relay 27, to cause the short circuit of relay 24 which now becomes deenergized. With the deenergization of relay 24 while relay 27 is still energized, a circuit is established from ground, the right hand armature and back contact of relay 24, front contact and right hand armature of relay 27, the left hand armature and front contact of relay 31 to cause the short circuit of relay 28 which now releases in turn releasing relay 32. Thus, relay 32 has been maintained energized over the seventh, eighth, ninth and tenth periods, a total period of two seconds.

At the beginning of the twelfth period, ground is removed from conductor 19 whereupon relay 22 is released, resulting in the release of relay 27. Through the release of relay 27, relay 31 becomes deenergized and at this time all the relays in this group are at normal.

At the beginning of the thirteenth period, this entire cycle of operations begins over again. Thus, it will be seen that out of twelve periods, relay 32 is energized for a total of four periods and deenergized for a total of eight periods, meaning that the relay 32 operates periodically to connect the source of ringing current 33 through its armatures and front contacts to conductors 34 and 35 for a period of two seconds and to connect ground and battery through its back contacts and armatures to these conductors for a period of four seconds.

It will be seen that while relay 13 is periodically placing ground on the conductor 19 for half-second periods that relay 22 is also periodically closing its left-hand outer contact for one-second periods. It has been seen that relay 11 is energized during the energization of relay 4. During its periods of energization an alarm 36 is operated from the source of current 33, through the closure of the right hand armature and front contact of relay 11. Also during these periods ground connected to conductor 37 through the closure of the outer left hand armature and front contact of relay 22 is disconnected from a pair of relays 38 and 39. In the same manner the ground on conductor 8 is disconnected from the holding circuit for relays 38 and 39 and transferred to conductor 7 for the purpose of maintaining an additional holding ground for relay 6. It will be realized that relay 11 will be operated for a period of two seconds and released for a period of four seconds in accordance with the ringing current incoming from the distant central office. These periods do not necessarily correspond in point of time to any period defined by relay 22. We will therefore assume the worst condition, that is, when relay 11 becomes energized at the same instant that relay 22 becomes energized and for purposes of explanation we will now assume a new series of periods, in this case, each of one-second duration.

At the beginning of the first period, relay 22 will become energized and relay 11 will operate.

At the beginning of the second period, relay 22 will release but relay 11 will be maintained operated through the two-second energization which it receives under control of relay 4.

At the beginning of the third period, relay 22 will become energized and at this time relay 11 will become deenergized. Upon the deenergization of relay 11 a circuit is established from ground on conductor 8, through the outer left hand armature and front contact of relay 22, conductor 37, back contact and inner left hand armature of relay 11, alternate contacts of the left hand armature of relay 38, winding of relay 38, resistance 40, to

battery and ground. Relay 38 becomes energized in this circuit and locks to ground on conductor 8 through the outer left hand armature and back contact of relay 11, left hand armature and alternate contact of relay 38. Relay 39 is short circuited at this time through its own left hand armature and back contact.

At the beginning of the fourth period, relay 22 becomes deenergized and by removing ground from the left hand armature of relay 39 allows this relay to become energized through the ground supplied from conductor 8 over the outer left hand armature and back contact of relay 11, left hand armature and alternate contact of relay 38, winding of relay 39, resistance 41, to battery and ground.

At the beginning of the fifth period, relay 22 again operates, thus again placing ground on conductor 37 which results in the short circuit of relay 38 and this relay therefore releases. Through the release of relay 38, ground on the conductor 8 is connected through the outer left hand armature and back contact of relay 11, right hand armature and back contact of relay 38, front contact and right hand armature of relay 39, alternate contacts of the left hand armature of relay 42, resistance 43, to battery and ground. Relay 42 becomes energized in this circuit and through its right hand armature places an additional ground on conductor 7.

At the beginning of the sixth period, relay 22 releases whereupon ground being removed from conductor 37 relay 39 is released. With both relays 38 and 39 released and relay 42 operated the short circuit about the winding of relay 12 is removed and this relay now operates. Although by its operation relay 12 removes ground from conductor 7, this conductor is maintained grounded through the right hand armature and front contact of relay 42 as just described.

At the beginning of the seventh period, relay 11 again operates, resulting in the immediate deenergization of relays 42 and 12 whereby relays 12, 38, 39 and 42 are returned to normal to thus prevent the possibility of removing ground from conductor 7. This condition will be maintained as long as relay 11 is periodically operated for periods of two seconds and released for periods of four seconds. If, however, before the beginning of the seventh period, relay 4 has become permanently deenergized as by the abandonment of the connection from the central office then the operation of relay 22 and the failure of relay 11 to reoperate will result in the extension of ground from conductor 8 through the outer left hand armature and front contact of relay 22, conductor 37, back contact and inner left hand armature of relay 11, alternate contacts of the left hand armature of relay 38, to the winding of relay 38 to cause its operation. Upon this second operation of relay 38, ground supplied over conductor 8 through the outer left hand armature and back contact of relay 11, to the right hand armature of relay 38, is opened at this point so that relay 42 becomes deenergized. Upon the deenergization of relay 42 while relay 12 is energized and relay 11 is deenergized, ground will be removed from conductor 7 and as a consequence relay 6 will be released.

From the foregoing description it will be seen that upon the energization of relay 4 and the consequent energization of relay 6 that signal lamp 45 will operate and that this lamp will remain operated so long as ringing current comes in over conductors 1 and 2 from the central office even though this ringing current is periodically applied for periods of two seconds and disconnected for periods of four seconds. Signal lamp 45 and multiples thereof together with associated signal lamps 46 and 47 for other incoming trunks, and alarm 36 and multiples thereof, are placed at strategic points about the premises wherein a P. B. X. of this nature is installed. Any one of the subscribers noting the lighted condition of lamp 45 and hearing the alarm 36 may answer the incoming call.

Let it be assumed that the subscriber at substation 48 answers the incoming call. In this case he will operate trunk key 49 which through a well known mechanical locking arrangement will be maintained operated until manually released. The subscriber at substation 48 will then remove his receiver from its hook whereupon a circuit will be established from battery, trunk relay 50, contacts 51 and 52, of key 49, resistance 53, contacts 54 and 55 controlled by hook switch 56, winding of marginal relay 57, to ground. With resistance 53 included in this circuit, relay 50 will become energized but relay 57 will fail to operate. Upon the operation of relay 50 a circuit is established from ground, front contact and right hand armature of relay 50, winding of relay 58, normal contact and inner right hand armature of relay 58, inner right hand armature and back contact of relay 5 to battery and ground. Relay 58 operates in this circuit and holds through the alternate contacts of its inner right hand armature, winding of relay 5, to battery and ground. Relay 5 now becomes operated and removes ground from conductor 7. The trunk conductors 1 and 2 are now connected through the front contacts and left hand armatures of relay 58 to the talking conductors leading to substation 48 whereupon the well known tripping relay at the central office is energized, ringing current is stopped, and the talking condition is established. Relay 4 becomes deenergized and since ground is now removed from all of conductors 7, 8, 9 and 10, the relays of the ringing and timing circuit are restored to normal and signal lamp 45 becomes dark.

It will be noted here that should another subscriber now attempt to make connection to this central office trunk, such connection will be prevented through the removal of the battery connection from the back contact and inner right hand armature of relay 5.

As an illustration we will assume that the subscriber at substation 160 removes his receiver from his hook and operates trunk key 161 whereby relay 162 becomes energized. Due to the fact that relay 5 is energized relay 163 cannot become energized. Therefore, a circuit will be established from ground, the contacts of the outer left-hand armature and front contact of relay 162, conductor 164, winding of relay 165 to battery and ground. Relay 165 attracts its armatures and cuts off the connection of the subscriber's line to line relay 166. At the same time a circuit is established from ground, outer left hand armature and front contact of relay 162, outer left hand armature and back contact of relay 163, over the loop of the subscriber's line, the inner left hand armature and back contact of relay 163, the inner left hand armature and front contact of relay 162, conductor 167, which may be traced through Figs. 2, 3, 5 and 6 to the winding of relay 168 and thence to battery and ground. Relay 168 becomes energized in this circuit and through its armature and front contact causes the operation of relay 132. Relay 132 in turn places ground on conductor 9 thereby starting the ringing and timing circuit relays into operation. Relay 132 through its inner right hand armature and front contact also energizes the tone relay 122 so that this relay now connects a source of tone from its left hand winding, through condenser 123, the outer right hand armature and front contact of relay 13, during its periods of energization, through the outer right hand armature and front contact of relay 132, condenser 169 to conductor 167 whence it is connected to the subscriber's station 160. This constitutes a busy tone which notifies the subscriber thereat that the trunk reached through the manipulation of key 161 is busy.

The subscriber at substation 48 now communicates with the subscriber calling over the trunk. In the present instance we will assume that it is the subscriber at substation 59 who is wanted. Therefore the subscriber at substation 48 will call the subscriber at substation 59, inform him of the incoming call on the first central office trunk and then abandon the connection. The first act is to establish a holding condition on the trunk. This is done by pressing key 60. It will be noted that of the five keys 49, 60, 61, 62 and 63 at substation 48, that key No. 60 is shown in somewhat different form than the others. This is to indicate that key No. 60 is non-locking and as soon as the finger is taken off it will restore to its normal condition. The other keys, however, are mechanically arranged so that the depression of one will restore any other which has been previously operated and maintain the one in operated position. When in the present instance key 60 is depressed resistance 53 is momentarily short-circuited. This results in the momentary energization of relay 57. Therefore a circuit is established from ground, front contact and armature of relay 57, front contact and outer right hand armature of relay 58, winding of relay 64 to battery and ground. Relay 64 becomes energized and through its right hand armature and outer left hand armature connects the winding of relay 65 across the conductors 1 and 2. Relay 65 is now energized by the current supplied at the central office and upon operation closes a circuit for the energization of relay 66. Relay 66 upon energizing opens a short circuit about the winding of relay 67 which is now serially included in the circuit leading to substation 48. Relay 67 therefore becomes operated and through its right hand armature completes a locking circuit for relay 64 so that this relay does not deenergize when key 60 is returned to normal.

The subscriber at substation 48 now operates local key 61. This key has no contacts and does not produce any direct circuit change, but its operation unlocks key 49 which upon restoring opens the circuit of relay 50. Relay 50 in turn releases relay 58 so that substation 48 is now disconnected from the trunk circuit. Upon the release of relay 58 relay 67 becomes deenergized resulting in turn in the deenergization of relay 64. Relay 65, however, is maintained energized in a circuit from conductor 1, the left hand armature and back contact of relay 67, winding of relay 65, the armature and front contact of relay 66 to conductor 2. This forms a shunt across the conductors 1 and 2 which will hold the connection at the central office.

Since the subscriber at substation 48 now has his receiver off the hook a connection is established from ground, back contact and right hand armature of relay 68 in the tone circuit in Fig. 6, conductor 69 which may be traced from Fig. 5 to Fig. 3 and thence through the left hand winding of relay 70, the back contact and left hand armature of relay 71, the back contact and left hand armature of relay 72, conductor 73 to and through the loop of substation 48, conductor 74, inner right hand armature and back contact of relay 72, right hand armature and back contact of relay 71, right hand winding of relay 70 to battery and ground. Relay 70 becomes energized in this circuit.

A connection is now established from ground, the right hand armature and contact 75 of relay 70, the left hand armature and back contact of relay 76, contacts 77 and 78 of relay 79, right hand winding of relay 80 to battery and ground. Relay 80 becomes

energized in this circuit whereupon a circuit is established from ground, the winding of relay 90, the right-hand armature and back contact of relay 91, conductor 92, inner left hand armature and front contact of relay 80, left hand winding of relay 80 to battery whereby relay 80 becomes locked in a circuit independent of its right hand winding. Upon the energization of relay 90 a circuit is established from ground, left hand armature and front contact of relay 90, conductor 89, winding of relay 79 to battery and ground. Relay 79 becomes energized in this circuit and its armature is mechanically locked in operated position by means of latch 93 which is under control of relay 94. Upon the energization of relay 79 the original energizing circuit of relay 80 is opened, but this relay is held in the locking circuit just described.

Also upon the energization of relay 70, conductors 81, 82 and 83 leading respectively to the left hand windings of relays 84, 85 and 86 of the three link circuits are connected to ground. Therefore upon the energization of relay 80 ground on conductor 81 connected through the left hand winding of relay 84 is now extended through the inner right hand armature and front contact of relay 80, conductor 87, back contact and armature of relay 88 to battery and ground. Relay 84 becomes energized and establishes a circuit from battery and ground, right hand winding of relay 84, front contact and outer right hand armature of relay 84 to ground on conductor 89 whereby relay 84 becomes locked in a circuit independent of its left hand winding.

Upon the energization of relay 84 a connection is established from ground, the inner right hand armature and front contact of relay 84, winding of relay 71 to battery and ground. Relay 71 cuts off the windings of the line relay 70 and extends the talking conductors 73 and 74 to conductors 95 and 96 respectively which now through the left hand armature and front contacts of relay 84 are extended to conductors 97 and 98 respectively and from thence through the left hand winding to ground and the right hand winding to battery of relay 99 so that relay 99 supplying current over the loop of substation 48 now becomes energized. Relay 99 establishes a connection from ground, armature and front contact of relay 99, winding of relay 100 to battery and ground. Relay 100 becoming energized establishes a circuit from battery and ground, winding of relay 101, front contact and armature of relay 100, normal contact traversed by switch arm 102, normal contact of the left hand armature of relay 91 to ground. Relay 101 becomes energized in this circuit and through its inner right hand armature establishes a circuit for the energization of relay 103. This relay through its right hand armature places a ground on the conductor 89 and through its left hand armature causes the energization of relay 91. Relay 91 through its alternate contact and left hand armature now maintains relay 101 energized through a direct connection not including the normal contact of brush 102. Upon the energization of relay 91 the circuit for relay 90 is opened and this relay restores to normal. Relay 90 being in series with the holding winding of relay 80, relay 80 now becomes deenergized.

It will be noted at this point that should another call now be originated whereby conductor 104 is grounded as before, that such ground will now be extended through the left hand armature and back contact of relay 76, contacts 105 and 106 of relay 79, back contact and outer left hand armature of relay 80, left hand armature and back contact of relay 107, contacts 108 and 109 of relay 110 to the right hand winding of relay 111. Relay 111 it will be noted controls the second link circuit so that upon the energization of relay 84 hereinbefore described the starting circuit is advanced.

In this connection it will furthermore be noted that through the energization of relay 88, battery is removed from conductor 87 so that no one of the line finder relays such as 84 shown on a horizontal line to the right thereof may become energized. The link circuit is now in a condition awaiting reception of dial pulses from the substation 48.

Upon the energization of relay 90 hereinbefore described and the subsequent energization of relay 103, whereby ground is placed on conductor 89, a circuit is established from such ground, through the normal contacts of the armature of relay 114, brush 117 and its normal contact, through the winding of relay 119, to battery and ground. Relay 119 is known as the dial tone relay and through its right hand armature connects ground to conductor 120 leading through resistance 121, the back contact, armature and right hand winding of relay 122 to battery. Since this circuit includes the back contact of the relay which becomes energized therein, the relay will vibrate its armature rapidly and through induction will transmit a tone through its left hand winding, condenser 123 over conductor 124, thence through the front contact of the right hand armature of relay 119, condenser 125, through the right hand winding of relay 99 to battery. Thence by induction this tone will be transmitted to the subscriber's station 48, notifying the subscriber that he may proceed with the dialing operation.

It has been assumed that the subscriber at substation 48 wishes to communicate with the subscriber at substation 59. He will therefore operate his dial to send three impulses each of which will here consist of a momentary opening of the line with the consequent momentary deenergization of relay 99. Upon the first deenergization of this relay a circuit

is established between ground, armature and back contact of relay 99, outer right hand armature and front contact of relay 101, right hand armature and back contact of relay 112, innermost right hand armature and back contact of relay 113, winding of relay 114, winding of stepping magnet 115, to battery and ground. Relay 114 becomes energized in this circuit and opens the circuit for dial tone relay 119, whereby dial tone is cut off from the calling subscriber's line. Also through the movement of its armature, relay 114 causes the energization of relay 126 which prepares a circuit for the subsequent energization of relay 113. The ground for operating the stepping magnet 115 is also extended through the armature and back contact of magnet 115, the left hand armature and front contact of relay 101, the winding of relay 116, to battery and ground. Relay 116 through its right hand armature provides a substitute ground for holding relay 100 operated, and through its right hand armature provides a ground to supplement that from the back contact of relay 99, whereby a ground is definitely maintained on the winding of stepping magnet 115 until it has completely operated. This insures that the magnet 115 will take a full step even though the momentary deenergization of relay 99 is of such short duration that it would not ordinarily produce this result. Upon the subsequent energization of relay 99 and when the magnet 115 has become fully energized, its circuit will then become opened and upon its release will drive brushes 102 and 117 on to their first working contacts. Relay 114 tends to become deenergized at this time, but due to its slow releasing characteristics will hold its armature operated during a full series of impulses. In this manner the magnet 115 is energized three times in succession so that brush 117 comes to rest on the terminal connected to conductor 118.

Conductor 118 leads to relay 127 in Fig. 3, so that upon the deenergization of slow release relay 114 a circuit is established from ground on conductor 89, through the normal contacts of the armature of relay 114, brush 117, conductor 118, winding of relay 127 to battery and ground and this relay now becomes operated.

For purposes of illustration it will first be assumed that the line leading to substation 59 is busy. In this case the cut-off relay 128 will be operated and a ground will be found on conductor 129. Therefore the ground on conductor 129 will be extended through the right hand armature and front contact of relay 127, conductor 130, armature and front contact of relay 126, winding of relay 113 to battery and ground. Relay 113 responds and locks through its inner left hand armature to ground on conductor 89. This action takes place shortly after the deenergization of relay 114, by virtue of the slow releasing characteristics of relay 126 which holds its armature operated for an instant after the link connector relay 127 has become operated. Relay 113 in operating performs a number of functions. First, through its innermost right hand armature it opens the pulsing circuit so that the switch will be prevented from stepping should another digit be dialed. Secondly, relay 113 opens the sleeve circuit from the back contact of relay 126 so that relay 112 is prevented from operating. Thirdly, relay 113 through its outermost right hand armature and front contact places ground on conductor 131 which connects through the winding of relay 132 to battery and ground. Relay 132 through its left hand armature places a ground on conductor 9 which in turn energizes the ringing and timing relays in the manner hereinbefore described. Through its inner right hand armature relay 132 energizes the tone relay 122 so that a tone is now connected to conductor 124 and thence through the outer right hand armature and front contact of relay 13 during its periods of energization, through the outermost right hand armature and front contact of relay 132, condenser 133, conductor 134, front contact and middle right hand armature of relay 113, condenser 135, right hand winding of relay 99 to battery, whence through induction the busy tone is periodically applied through the calling subscriber's line and the calling subscriber is thereby notified that the called line is busy. The circuit will remain in this condition until the subscriber at substation 48 replaces his receiver on its hook. At this time the link circuit will be restored to normal.

Let it now be assumed that the line leading to substation 59 is idle. In this case relay 113 will fail to operate since it will be connected to the battery of the relay 128. Therefore in a short interval relay 126 will release and by switching conductor 130 from the winding of relay 113 to the right hand winding of relay 112, will now establish a connection from the battery of relay 128 to the ground of the relay 112, whereupon both of these relays will become energized. Relay 112 locks through its left hand winding to the ground on conductor 89 and by its right hand armature opens the pulsing circuit to prevent the switch from stepping if another digit is dialed. Through its left hand armature and front contacts relay 112 extends the ground on conductor 89 through the middle lower armature and back contact of relay 136, through the winding of relay 137 to battery and ground. Relay 137 becomes operated, and through its inner lower armature places a ground on conductor 130 to operate the cut-off relay 128. Ground on conductor 129 marks this line as busy.

Relay 137 through its inner upper armature and front contact places a ground on

conductor 9, and starts the relays of the ringing and timing circuit in operation. Through its outer armatures relay 137 connects the talking leads 138 and 139 respectively to conductors 34 and 140. As conductor 140 extends through the winding of relay 141 to conductor 35 it will be seen that interrupting ringing current is now connected to conductors 138 and 139 and thence through the front contacts and left hand armatures of relay 127 to conductors 142 and 143 respectively and thence through the front contacts and armatures of cut-off relay 128, to the conductors leading to substation 59.

It will be noted that substation 59 is shown in a different manner from substation 48. This is to illustrate the modern circuits used in connection with the handset. The bell at the substation 59 will respond to the ringing current now being transmitted thereto, but relay 141 not receiving sufficient current for its energization will fail to operate. Relay 136 at this time is shunted through the back contact of relay 141 so that it does not operate. During the transmission of ringing current to the called subscriber's line, a small amount is shunted through conductor 139, through condenser 144, the back contact and middle right hand armature of relay 113, condenser 135, through the right hand winding of relay 99, whence by induction the calling subscriber at substation 48 is notified that substation 59 is being rung. When the handset at substation 59 is lifted from its stand, the contacts 145 are operated, thus putting the transmitter and receiver in circuit and increasing the current flow in relay 141 to the point where this relay becomes operated. The shunt around the winding of relay 136 is now removed and this relay becomes operated in a circuit from battery, resistance 146, winding of relay 136, front contacts and left hand armature of relay 112 to ground on conductor 89. The operation of relay 136 opens the circuit of relay 137 and this latter relay in releasing disconnects ringing current from the called line and removes the ground from conductor 9. Relay 136 also provides a substitute ground for the sleeve conductor 130 and through its inner armatures and front contacts extends the talking circuit through from said substation 48 to substation 59. Talking current for substation 48 is provided through the windings of relay 99 and talking current for substation 59 is supplied through the windings of retardation coil 147.

The subscriber at substation 48 now informs the subscriber at substation 59 that he is wanted on a call coming in over the central office line represented by conductors 1 and 2. Without further ado the subscriber at substation 59 presses trunk key 149 whereupon a connection is established from battery and ground, winding of relay 150, contacts 151 and 152 of key 149, resistance 153, contacts 154 and 155, winding of relay 157 to ground. Relay 150 becomes energized in this circuit and through its upper left hand armature places a ground on conductor 148, which may be traced through Fig. 2 to the winding of relay 156 in Fig. 3.

Relay 156 immediately cuts off connection between the substation 59 and the link circuit and through its outer right hand armature places a ground on conductor 129 so that when relay 127 shortly becomes deenergized, the line leading to substation 59 will be marked as "busy".

Upon the energization of relay 150, relay 158 will become energized in a circuit from ground, the front contact and right hand armature of relay 150, winding of relay 158, normal contacts of the inner right hand armature of relay 158, inner right hand armature and back contact of relay 5 to battery and ground. Relay 158 becomes operated and locks through the alternate contacts of its inner right hand armature to the winding of relay 5, thereby opening the battery connection so that no other relay such as 58 shown on the same horizontal line therewith may be operated. Relay 158 through its left hand armatures and front contacts connects the substation 59 to the trunk conductors 1 and 2. Relay 67 being in the series therewith becomes operated and by opening the circuit of relay 65 allows this relay to become deenergized. Upon the release of relay 65, relay 66 becomes deenergized and thence in turn short circuits the winding of relay 67 so that the trunk holding circuit is now returned to normal.

The subscriber at substation 48 now having delivered his message replaces his receiver on its hook thereby causing the deenergization of relay 99. In a short interval relay 100 becomes deenergized, followed shortly thereafter by the release of relay 101. This in turn releases relay 103, whereby ground is removed from conductor 89 and relay 91 is allowed to return to normal. Relay 91 returning to normal extends a circuit from ground through the normal contact of its left hand armature, brush 102 to the contact on which this brush is now resting, through the back contact and armature of stepping magnet 115, winding of relay 114, winding of magnet 115 to battery and ground. Magnet 115 is now in a self-interrupting circuit and will automatically step the brushes 102 and 117 to their normal position. When ground has been removed from conductor 89 and brushes 102 and 117 have been restored to normal, then the line finder relay 84 and the connector relay 127 are released, so that the link circuit is now entirely restored to normal.

In this connection it will be noted that of all the relays which were energized during

the establishment of the link circuit connection, 79 is the only one now remaining operated. This is, however, due to the mechanical latch 93. This arrangement insures that the next local call will be established through the second link circuit, that is, the upper one shown in Fig. 4 and through a similar arrangement the third link circuit shown in the lower part of Fig. 4 will be the next to be used. Upon the energization of relay 148 corresponding to relays 110 and 79 and the deenergization of relay 149 corresponding to relays 111 and 80, a circuit is completed from battery, winding of relay 190, outer right-hand armature and back contact of relay 149, front contact and right-hand armature of relay 148, outer right-hand armature and back contact of relay 111, contacts 191 and 192 controlled by relay 110, outer right-hand armature and back contact of relay 80, contacts 193 and 194 controlled by relay 79 to ground. Relay 190 becomes energized in this circuit and through its left hand armature and front contact places a ground on conductor 195 leading in multiple to the windings of magnets 196 and 94. Magnet 196 will unlatch the armature of relay 110 and magnet 94 will unlatch the armature of relay 79 so that if either or both of these link circuits have now become idle, they will be returned to normal condition and the circuit for relay 190 will be opened. If on the other hand all three link circuits are busy, then relay 190 will be maintained energized in the circuit just traced and through its right-hand armature will place a ground on conductor 197 which may be traced through Figs. 4, 3, 5 and 6 to the winding of relay 68. This relay through its left-hand armature places a ground on the winding of relay 132 so as to start the ringing and timing circuit relays into operation. Through its inner right-hand armature relay 68 removes the ground from conductor 69 so that any other subscriber attempting to make a local call will find the circuit of his line relay open. A busy tone will be connected through the outer right-hand armature and front contact of relay 132, condenser 198, the outer right-hand armature and front contact of relay 68 into the windings of transformer 159 whence by induction busy tone is transmitted through the front contact and inner right-hand armature of relay 68 and thence over conductor 69 to the tip windings of the line relays so that the subscriber who is attempting to make a local call will receive a busy tone and will be notified thereby that all link circuits are busy.

Each link circuit is provided with a relay such as 76 and a key such as 170 so that should it become disabled, the starter wire may be permanently advanced to the next link circuit, by the operation of the key and the consequent energization of the relay.

Each link circuit such as that shown in Fig. 5 is provided with a separate battery feed conductor. In this case fuse 171 is provided in the battery feed circuit for the apparatus shown in Fig. 5 but for the sake of simplicity all of the connections thereto are indicated in the conventional manner rather than shown leading to this fuse. The fuse, however, is of such a nature that when it is blown a link will complete a connection from busbar 172 to terminal 173 so that battery will now be connected to conductor 174. Conductor 174 may be traced through Figs. 6, 5 and 3 to the normal contact of key 170 and thence to the winding of relay 76 so that this relay now becomes operated and automatically advances the starter wire. Upon the energization of relay 76 battery on conductor 174 is connected through the inner right-hand armature and front contact of relay 76 of conductor 175 which may be traced through Figs. 3, 5 and 6, to the winding of alarm relay 176. Relay 176 becomes energized and causes the operation of alarm 177 and signal lamp 178. Relay 176 is also connected to busbar 179 so that if any one of the fuses 180, 181 or 182 leading to other apparatus of the P. B. X. operates, a similar alarm will be given.

What is claimed is:

1. In a telephone system, lines, a plurality of links for interconnecting said lines, trunks for extending said lines, and means responsive to the extension of one of said lines over one of said trunks for opening the said line to said links.

2. In telephone system, lines, a plurality of links for interconnecting said lines, trunks for extending said lines, each of said lines having access points to said links and said trunks, and means responsive to the appropriation of one of said trunk access points by one of said lines for cutting off said link access points of the said line.

3. In a telephone system, lines, links for interconnecting said lines, and trunks for extending said lines, each said line extending to a plurality of sets of permanently paired contacts for connecting said line to said trunks and to a plurality of sets of permanently paired contacts for interconnecting said line and said links, and means responsive to a connection established from said line to one of said trunks for disconnecting said line from said plurality of sets of permanently paired contacts for interconnecting said line and said link.

4. In a telephone system, lines, a plurality of links for interconnecting said lines, trunks for extending said line, link relays and trunk relays for interconnecting said line and said links and said line and said trunks, and a relay responsive to the actuation of one of said trunk relays for opening said line to said link relays.

5. In a telephone system, a substation, a

line extending therefrom to a plurality of trunk relays, said line extending therefrom to a plurality of line circuit relays including a line relay, a cut-off relay and a link cut-off relay, said line further extending therefrom to a plurality of link relays, and means responsive to the actuation of one of said trunk relays for actuating said link cut-off relay.

6. In a telephone system, a substation, a line, a plurality of trunks, a relay per trunk for connecting said line to said trunks, said line extending from said substation to said trunk relays, a line circuit including a line relay, a cut-off relay and a link cut-off relay, said line further extending from said trunk relays to said line circuit, a plurality of links, an answering and a calling relay per link for interconnecting said line and said links, said line further extending from said line circuit to said link relays, and means responsive to the actuation of one of said trunk relays for actuating said link cut-off relay.

7. In a telephone system, a substation, a line, a plurality of trunks, a relay per trunk for connecting said line to said trunks, said line extending from said substation to said trunk relays, a line circuit including a line relay, a cut-off relay and a link cut-off relay, said line further extending from said trunk relays to said line circuit, a plurality of links, an answering and a calling relay per link for interconnecting said line and said links, said line further extending from said line circuit to said link relays, and means responsive to the actuation of one of said trunk relays for actuating said link cut-off relay and for establishing a busy condition at said calling link relays.

8. In a telephone system, lines, trunks, a relay per line per trunk for connecting said lines to said trunks, each said line having a pair of talking conductors and a signaling conductor per trunk, each said line terminating in a station equipped with a hookswitch, and means under joint control of said hookswitch and said signaling conductors for selectively actuating said relays.

9. In a telephone system, lines, trunks, a relay per line per trunk for connecting said lines to said trunks, each said line having a pair of talking conductors and a signaling conductor per trunk, each said line terminating in a station equipped with a hookswitch and a plurality of signaling keys, and means under joint control of said hookswitch and said signaling keys for selectively actuating said relays.

10. In a telephone system, lines, trunks, a relay per line per trunk for connecting said lines to said trunks, each said line having a pair of talking conductors and a signaling conductor per trunk, each said line terminating in a station equipped with a hookswitch and a plurality of mechanically interlocked locking keys each said signaling conductor being under control of one of said keys, and means under joint control of said hookswitch and said keys for selectively actuating said relays.

11. In a telephone system, lines, trunks, a relay per line per trunk for connecting said lines to said trunks, each said line having a pair of talking conductors and a signaling conductor per trunk, each said line terminating in a station equipped with a hookswitch, links, an answering relay per line per link and a calling relay per line per link, a line circuit including a line relay, a cut-off relay and a link cut-off relay for each said line, and means under joint control of said hookswitch and said signaling conductors for selectively actuating said trunk relays and for actuating said link cut-off relay.

In witness whereof, I hereunto subscribe my name this 12th day of March, 1929.

LANGFORD J. BOWNE.

In witness whereof, I hereunto subscribe my name this 12th day of March, 1929.

CHARLES D. KOECHLING.