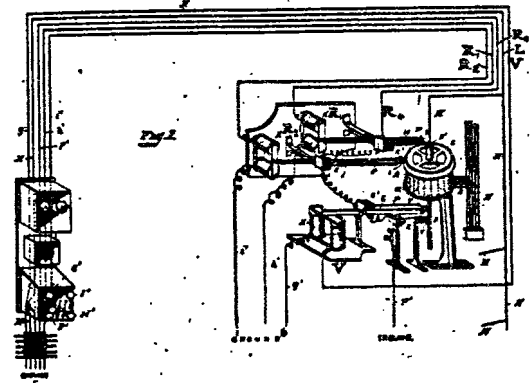
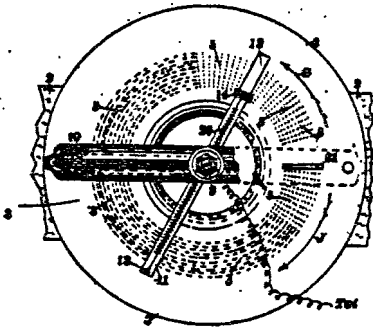
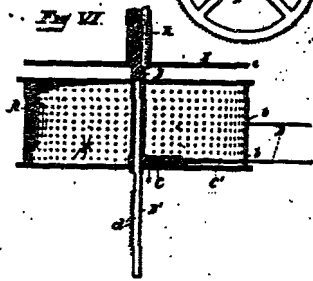
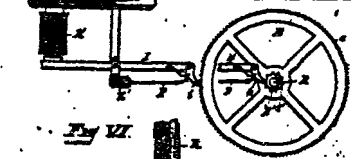
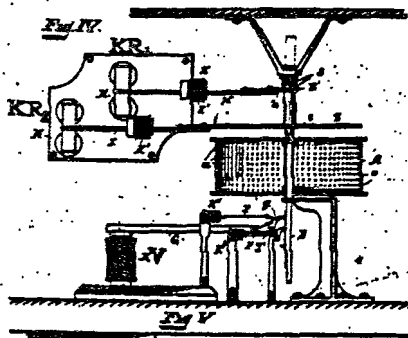
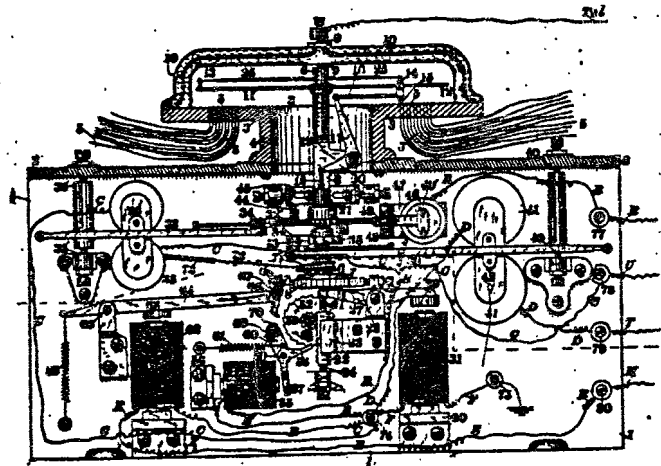


The Early History of the Automatic Telephone



Drawings of some of the very earliest automatic switches



Arthur Bessey Smith
Telephone History Institute

The Early History
of the
**Automatic
Telephone**

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1995

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The Early History of the
Automatic Telephone

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Table of Contents

1.	Background	1
2.	Connolly and McTighe system	1
3	Smith's Automatic Telegraph Trunk Selector	6
4	Early history of the Strowgers	8
5	First Strowger automatic switch	9
6	Exhibiting the system	10
7	The flat disk switch	11
8	The first public system	14
9	The Erickson System and Lundquist	15
10	The piano wire switch	20
11	Revised piano wire switch	22
12	Plaster of paris banks	27
13	Party line systems	27
14	The first dial	28
15	Early trunking systems	30
16	First telephone trunking system	32
17	The Automatic Telephone Exchange Company	33
18	The Augusta System	33
19	Company Organization	35
20	The 1,000 line system	35
21	The New Bedford System	36
22	The Fall River System	40
23	The Chicago System	43
24	Summary of events through 1902	48
25	The Dayton System	51
26	The Grand Rapids System	53
27	The Los Angeles Multi-Office System	53
28	The Battle Creek System	59
29	Switchroom Layouts	61
30	Keith Line Switch	64
31	The sub-office	66
32	Party Lines	67
33	South Bend and Common Battery	69
34	Trunk Repeaters	72
35	The Lorimer System	73
36	Callender's First System	74
37	Callender's Second System	74
38	Strowger and Callender Compared	75
39	Callender's Second New York System	76
40	The Return to Brantford	77
41	Beginnings of the Lorimer System	78
42	Remodeling the system	79
43	The completed Lorimer System	80
44	Lorimer summary	86

Preface

This book contains the single best and most detailed "eye witness" account of the early development of automatic systems that I am aware of. Arthur Bessey Smith was surely one of the most knowledgeable early telephone engineers. Most of his other writings saw the light of day in book form. This one apparently did not.

Much early information on the development of automatic service has been forgotten, and has left the public consciousness. Some of the forgotten information appears here. Without this book, many important details on the history of automatic systems, probably would no longer be available to the public.

The "book" came to the Institute as a scrapbook of clippings, apparently gathered from some long-discontinued publication. The most likely suspect is Automatic Electric's excellent journal *Automatic Telephony*. Unfortunately, we have been unable to get access to issues of this magazine prior to 1919. No name of the careful collector appears in the book nor was there a date. We do not know whether the "book" is complete. The collector may have missed some of the materials.

While using information from this book, one day it came to me that I had never seen any credits or acknowledgments in other writings that this material had been published in book form. A check through several dozen books and journal articles confirmed this suspicion. I have been unable to locate any reference to it, in either journal or book form.

When did Smith complete the articles? He discusses the Los Angeles system as having one manual and seven automatic offices. This dates that part of the manuscript not later than the fall of 1906. There is a short reference to the system at Columbus, Ohio in the spring of 1907, but several large dial systems ordered or installed after 1907 are not mentioned in the text.

Smith makes no mention of the new two-wire Strowger systems, which were first installed in 1908 at Pontiac, Illinois. There is no mention of the first automatic intermittent ringing, installed shortly afterward for the new dial system at Lansing, Michigan. And there is no mention of the landmark system at San Francisco, cut over in September, 1909. This was the first large city to use two-wire automatic equipment, and the first large city to have automatic ringing, and to provide subscriber-audible ringing signals. These were major improvements in automatic systems. Had the manuscript been written in 1908, it would surely have included all these new capabilities.

Most of the data on Lorimer systems reflect that system as it stood in 1901. Lorimer developments after 1901 are not mentioned. But the latest date in the book, used in one place only, refers to a Lorimer system in 1909. There is no conclusion, thus it is possible that later "chapters" are missing completely.

The original publications have a few chapter or section headings scattered through the book. Where Smith used these, I usually retained his heading exactly. Where there were no headings, I made them up.

A few incorrect dates — in the published versions — were later corrected in remarks printed in later clippings. These are retained in this book. In each case, the correct dates are widely known. I have handwritten the correct dates over each erroneous printed one.

There are two different figures numbered 26, and figures 78, 122 and 127 are missing.

Printing quality must have been satisfactory when originally published. Unfortunately, the paper in the scrapbook has aged and the ink has deteriorated.

You see the original type. This means that there are several different type fonts and sizes, and that columns are of slightly different width and length, reflecting the several original sources. One part of one page is from a different publication than that on another part of the same page.

The book was not intended to be a chronology of all the earliest automatic systems. Smith usually discusses only the first system of each new type of equipment, or each significant new change. In a few cases he mentions additional cities that used the same type of equipment. But, in most cases, he discusses only the first.

The story told in this book by Smith is not complete. There is no reference to Clark, Ness, Globe, Munson and others who were producing automatic systems at the time. Bell's Queens system went into and then was withdrawn from public service during the time period covered by the book. The original publications may have contained chapters on these systems also.

Smith includes only two systems outside the USA. One was the pilot system that went into service at Berlin, Germany on 21 May 1900, the second automatic system in Europe. And Smith mentions a Lorimer system being installed at Brantford, Ontario.

Smith may have covered these systems either in a fuller version of this manuscript, or in other publications. A portion of the manuscript may never have been published, and/or other portions may have been published in journals which were not available to the scrapbook maker.

Stanley Swihart
Telephone History Institute
Dublin, California
1995

1. Background

"Now faith is the substance of things hoped for, the evidence of things not seen."—Hebrews 11:1.

THE great things of the world have been the products of faith. The men who have written their names high have conquered by faith in their mission. From Abraham to Edison there is an inspiring record of achievements due to courage. If Cyrus W. Field had not been a man of sublime faith the Atlantic cable might not have become a working reality. If Dr. Alexander Graham Bell had not believed it possible to transmit speech electrically he would not have been able to carry his experiments to their successful conclusion. And the growth of the automatic telephone is more due to faith in possibilities than to anything else.

The importance of ready means of connection for telephone instruments has been recognized from the first. Private party lines soon reached the limit of their service. To converge all the lines at one central point for interconnection was the only way to extend the use of the telephone to meet the rapidly increasing demand. As telegraph lines had been switched by hand for years and was somewhat related to the newcomer in that it also employed relatively weak currents, electricians adapted the plug board to telephone use. From this beginning we have developed to the modern manual switchboard.

In the month of September, 1879, about three years after the invention of Bell's telephone, an application for patent was filed, which covered the first attempt at the automatic switching of telephone lines. The devices described were crude and inefficient, yet they were a beginning. They failed to make it a success. Yet since that time inventor after inventor has attacked the problem. It is a thing which could not be let alone. In spite of the hindrances of unskillful mechanics, their ignorance of electrical laws, and the manipulations of promoters, the automatic system has grown in efficacy and favor. Though men have been wrecked by the wayside, step by step the obstacles have been overcome till but few remain. It is my purpose to trace, as best I can, both technically and generally, the growth of the system, and to throw on the history such side lights as will be helpful from the lives of the men who did the work.

2. Connolly and McTighe system

M. Daniel Connolly, of Philadelphia; Thomas A. Connolly, of Washington, D. C., and Thomas J. McTighe, of Pittsburg, Pa., are the earliest known workers in this line. Their first patent was applied for September 10, 1879, and issued December 9 of the same year under the number 222,458. The condition of manual switchboards at that time may be guessed at by the following extract from the patent:

"The operation of making these connections is now altogether a manual work, and requires not only constant attention but much dexterity in order that there shall be as little delay as possible; but in exchanges comprising many members the work of the central office is very great, requiring many employes to meet the wants of the community. Even then there are incessant delays, much confusion, and consequently many mistakes and annoyances which it is highly important should be obviated."

While the drawings in the patent specifications are fairly clear, they are not in the best form for publication to show the essentials of their circuits. Accordingly I have redrawn the scheme in Figure 1. The substation

outfit consists of a talking circuit, containing the receiver, a signal circuit containing a polarized bell, and a selecting circuit containing a dial interrupter, a pole-changing switch, and several cells of battery. Two arrangements are shown in the patent, as at station No. 1 and station No. 3. In the latter the dial is entirely in the selecting circuit, while in the former it forms a part of the common circuit and must therefore be normally closed. This point is not definitely stated, though "interruptions" are mentioned as being made by the dial. This indicates that the dial was normally closed, but in selecting a number the circuit was *broken* instead of *made* a certain number of times. The bell was polarized so that positive current must enter at the binding post marked (+) in order to ring it. The reverse current would produce no effect.

The central office switch consisted of a number of wipers, W_1, W_2 , etc., mounted on the same shaft. On the end of each wiper was a hook. Arranged in the form of a quadrant around the shaft were a number of contact bars, B_1, B_2, B_3 , etc., each bearing as many hooks as there were wipers. Each wiper could be moved around

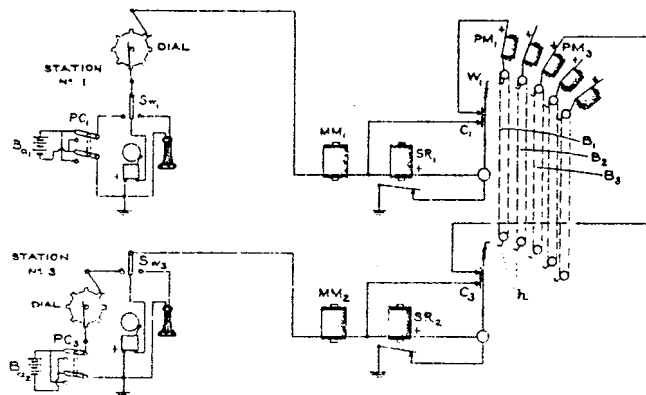


Figure 1.

on the axis and in so doing would engage a hook on each of the bars in succession. MM is a motor magnet which could move a wiper by a ratchet and pawl device. There was one motor magnet for each wiper. The line from a station was normally grounded at central through the contact of the switching relay, SR , which was polarized as indicated. Its armature was so arranged that it would stay in either position, not returning to its former position unless made to do so by current of the proper polarity. The private magnet, PM , was attached to a contact bar, and was arranged to pull the whole bar out of the path of the wipers. It was polarized, and there was one for each bar. It would stay in whichever position placed, the same as the switching relay.

In making a call there were three things which the user had to operate—the switch, Sw , the dial, and the pole-changer, PC . The switch stood normally on the center point, leading to the bell, and the pole-changer was up, connecting the positive pole of battery to the line. First, throw the switch to the left-hand point, connecting the battery to the line. Second, operate the dial. This interrupted the current and advanced the wiper. In so doing the current took the following path: From ground up through battery, through the dial to line, over the line to central, through the motor magnet, MM , through the switching relay, SR , to the wiper, through the contacts

of *SR* to ground. As the current flowed in the wrong direction through the switching relay, the latter would not be operated. In moving along to reach the desired bar, the wiper hooked into a hook on each intervening bar in succession, but passed on without disturbing them. Having arrived at the contact bar of the line with which our subscriber desired connection, he would, thirdly, throw the pole-changer down, thus reversing the battery. This reversal of battery produced three results—it operated the switching relay, *SR*, cutting off the ground at central; it operated the private magnet, *PM*, which pulled the contact bar, *B₃*, for instance, out of the way of any other wipers which might come around, at the same time carrying the hook on the wiper, *W₁*, along. The third effect was to ring the bell at the called station. Fourth, the calling subscriber shifted his switch, *Sw*, to the center point and waited for an answering signal from the other party. The called subscriber was supposed to answer by throwing current on the line in such a direction as to ring the calling subscriber's bell without reversing the current through the private magnet and the switching relay. Then they would both switch over to their receivers and talk. At the end of conversation the called subscriber switches back to the bell, while the calling subscriber switches to battery, reverses battery to push the bar, *B₂*, back in line, and bring the ground back on the wiper by means of the switching relay. The wiper was then free to go to any other line or return home.

Privacy, or non-interference, was secured in two ways. The calling subscriber's line passed through a contact, *C₁*, between the private magnet and the motor magnet. The first move of the wiper as it starts out to find another line breaks this contact, effectually preventing any other wiper from getting in on that line. The called line is protected by the withdrawing of the contact bar as above described.

There are several "bugs" in the system, which readily appear.

No. 1. It was expected to arrange the contact bars on a portion of a circle, which they called a quadrant. This would limit the number of subscribers very closely. Even if they had arranged a complete circle, the total number of lines possible to be served would be far too small to be practical.

No. 2. The work laid on the motor magnet is too heavy to be handled successfully by current over a long line to a sub-station. The battery to be maintained at the latter point would be enormous.

No. 3. Moving the contact bars back and forth is too heavy work for magnets, especially for polarized magnets, such as the private magnets.

No. 4. It was expected to be able to reverse the line current quickly enough to prevent the motor magnet from responding. This could not be done. The inventors made two suggestions of ways to make it sure. One was to provide a mechanical interlocking device so that when the switching relay, *SR*, pulled up it would block the motor magnet and prevent it from moving. But the same current which energizes the switching relay also energizes the motor magnet. As the latter is supposed to be quick enough in action to follow the impulses of current from the dial, the former would have to be exceedingly quick to pull up and block the motor magnet in time to do any good. The other suggestion was to make the contact on the hooks broad enough to allow the wiper to make one step without breaking contact. It must be noted in this connection that it required several impulses to move a wiper from one bar to the next.

No. 5. It will be impossible to get the answering ring as expected. In order that the positive selecting

current shall not ring the bell its plus terminal must be to earth as shown. This must be the case at all stations. The selecting current will pass from station No. 3 to central, the ringing and switching current will pass from station No. 3 through central to station No. 1. This direction is necessary to ring the bell at No. 1 without disturbing *PM* and *SR*. Now when the called subscriber answers, he must throw his current on the line in the same direction; that is, from station No. 3 to station No. 1. This is the wrong direction for ringing the bell of No. 1. He could ring it by sending current in the opposite direction, but that would operate *PM* and sever the connection by grounding the line at central.

No. 6. It would be necessary to talk through the coils, the motor magnet of each line and the switching relay and the private magnet of the calling line. This is too much for good service.

No. 7. There was no provision for release; that is, for automatically returning the wiper to its home position. If the switch had been made in the form of a complete circle it would be possible to return home by going on around the circle. The inventors suggested a complete circle for the purpose of increasing the number of lines, and even thought it possible to arrange the contact bars in a plane, with the hooks or wipers resting on a narrow belt running crosswise.

One suggestion of value was to run a separate wire for operating the switching relay and the private magnet, doing away with the reversal of current. This point seems not to have been embodied in the patent. A special application of their switch which the inventors expected to use was in the case of an office with a line to a distant factory. The switch could be placed at the end of the line in the factory and allow the office to pick up and converse with any department in the plant.

But to my mind the greatest obstacle in this system was the high percentage of connections which they insisted on handling. The maximum traffic is when all subscribers are connected by twos. This gives a ratio of cord circuits to lines of fifty per cent. It was this maximum which they tried to retain. Theoretically, it is a good thing for all the subscribers to be able to talk at once, but if telephone companies were to try to provide such facilities, telephone rentals on manual boards would be up in the clouds and the automatic would be an impossibility.

That the inventors themselves discovered the drawbacks of their system to some extent is shown by the development brought out about two years later. August 29, 1881, the same men applied for a patent on an improved system, which was later issued as No. 262,645. In this they show that the difficulty of working the magnets by line current had been found, and they get around it by using relays to control the magnets, the latter being supplied from battery at the central office. Figure 2 shows the essentials of the improved system. There is some discrepancy in the way the station was intended to be wired. In one drawing the strap of the switch, *Sw*, is shown as running to the plus terminal of the bell, as indicated by the broken line at station No. 1. In another drawing it is run to the other terminal of the bell according to the dotted line. Undoubtedly the former, the broken line, is the correct connection, for otherwise the bell could not be rung by an incoming call.

In this system the dial is clearly stated to be normally open. The pole changer, *PC₁*, is mounted on the dial in such a way that it will be automatically thrown to the reverse position when the impulses have ended. The operations of the subscriber are thus simplified.

The switch at the central office has been changed ma-

erially. Each contact bar, B_1, B_2 , etc., is carried by a pivoted arm, C , at top and bottom, so that it can be swung away from the path of the wipers. In swinging away it can operate a switch which breaks the contact between B and F and connects the bar directly to the line. The wiper arm carries a device called a "line tripper," whose plan is shown at LT_1 . The line from the station comes into the switch at F , passes through the contact to the spring B and to the polarized operating relay, OR_1 . From here it goes to the wiper arm, P_2 , out to the line tripper, LT_1 , through its back contact to P_1 and thus to the ground.

At the station Sw_1 is normally kept on its ground point so that calls may be received on the bell. When a call is to be made the subscriber puts the switch in the middle, which leaves it out of contact. The rotation of the dial sends impulses to central, positive current going over the line from the station. The operating relay closes and opens the local circuit of the motor magnet, MM_1 , causing it to move the arm by a ratchet movement. The first few impulses of current pass through the operating relay, OR_1 , and go to ground through P_1 . When the arm, P_2 , has advanced far enough, it engages the next contact bar, B_2 , pressing it out with a toggle-like movement of its line tripper. This brings the bar into elec-

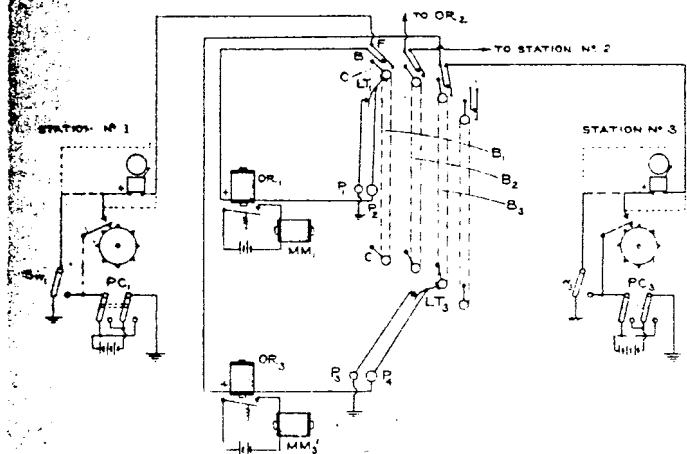


Figure 2.

trical contact with the spring leading to station No. 2, breaking off the connection to the operating relay of that line. At the same time the motion of the line tripper, LT_1 , breaks contact with its back spring, thereby cutting off the ground connection. The impulses for further advancement must now pass from the line tripper through the contact bar, B_2 , to line leading to station No. 2, and to earth through the bell of that station. As the impulses continue to come, the arm carrying the line tripper goes on, pushing past the bar so that it falls back to its normal position. This restores the connection of station No. 2 with its own operating relay and gives the line tripper, LT_1 , its direct ground through P_1 . Thus in advancing around the circle the impulses alternately find ground directly through P_1 and through the lines past which the arm moves. When the impulses cease, the line tripper will be resting against the bar of the line sought, pressing it out so as not to be caught by any other line tripper which may be putting up a connection. This removes the ground, P_1 , and cuts off the operating relay, OR_1 , of the called line, giving a direct line to the called station.

When the dial stops, it automatically throws the pole-changer, PC_1 , over and reverses the polarity of the battery. The subscriber now places the switch, Sw_1 , on the right hand contact, which sends current over the

line to the called station, ringing the bell. As the battery has been reversed, it will not affect the operating relay. An answering ring was intended to be sent the same as in the first system. Disconnection was effected by stepping on around the circle to the home point.

We have seen how privacy is secured by having the line tripper push the contact bar away from the center so that other trippers can not touch it. But another station might call on the home bar of the calling station if means are not taken to prevent it. A cam is arranged which rests in a notch as long as the arm is in the home position. When the arm starts out to find another line the cam rides up on a disc just enough to hold the bar beyond the reach of passing line trippers, but not enough to break the contact between B and F .

When the line tripper is in its home position it would be expected to be in contact with its own contact bar. This would press the bar out and break the contact $B-F$, which would cut the operating relay from the line. To prevent this, a notch is cut in the bar opposite its own line tripper, so that it can not be moved by the latter.

By going over the seven objections to the system which were mentioned above when treating the first patent, let us see how many of them have been remedied.

No. 1. We are still limited by the number of bars which can be placed in a circle of reasonable diameter.

No. 2. The motor magnet has been taken from the line and placed on a local circuit where it can have any reasonable strength of current without much expense for battery. The control of local circuits by relays is good and sound.

No. 3. The private magnet has been abolished. In its place is a light, pivoted device which ought to give less trouble.

No. 4. The reversal of battery current has now no effect on the motor magnet as in the first system, as the magnet is now in a local circuit and the operating relay is polarized.

No. 5. The answering ring is no better than before, unless, as the inventors suggest, the ringing current be employed, which is much weaker than that required to operate the operating relay. In this case, the called subscriber could send an answering ring to notify the calling station that he was there. The fancied necessity for the answering signal has entirely disappeared in these days. It must be that telephone subscribers were exceedingly slow about answering at that time.

No. 6. The number of coils through which conversation must be carried has been reduced from four to one. This is a very good move.

No. 7. The release is fairly good, though if a step should be lost or gained occasionally, after a time the subscriber might find himself far from home.

A few more troubles have appeared in getting rid of old ones. If wired as shown, the selecting current will ring the bell of its own station, for the polarity of the battery coincides with the wiring of the bell. It would be better to connect the contact point to the line side of the bell, according to the dotted line. In working around the circle the resistance of the working line is very greatly changed. At one instant it is merely that of the calling line, the next it is the sum of that line and the line past which it is moving. In these days of perfected relays this would occasion very little trouble, but relay making was not a finished art then. They had to be adjusted quite carefully for the length of line over which they were to work, and were very sensitive to changes.

October 29, 1881, M. D. Connolly, one of the original three, applied for a patent on improvements designed to overcome the difficulties above mentioned. The pat-

ent was issued under the number 263,862. The changes are not sufficient to warrant a drawing and are as follows: To equalize the current flow while working around the circle, he introduced a resistance in the ground wire at the central office, equal to that of the longest line. Further he inserted resistances in all lines except the longest to make them of equal resistance. If line No. 7 was the longest line, with a resistance of 20 ohms, and line No. 10 had 14 ohms resistance, he would add six ohms to the latter line to make it equal to the former. This method of getting rid of difficulty by "taking the bull by the horns" has something of the heroic in it. Instead of improving his relays, he equalizes the lines. While it ought to make all lines talk equally loud, it would hardly find favor today. It reminds one of the Thompson-Houston arc dynamo which had a spherical armature of high reactance. To get rid of the excessive sparking at the commutator, a small fan was built into the machine to blow out the arc by a blast of air.

Another improvement which Mr. Connolly made was the insertion of a polarized annunciator or drop in the ground circuit of each line at central. The polarity was so arranged that selecting current would not throw the drop, but if the called line was busy and connection therewith could not be obtained, when the calling station reversed the current to ring, it would throw the drop and let an attendant at central know that something was wrong. The need of a busy signal had been felt, and this was the best that could be done at that time. It had also been discovered that the switch did not always act as desired, and this polarized drop gave the opportunity for reporting or indicating cases of trouble.

A little later (Nov. 8, 1881,) Mr. Connolly changed the polarized drops to common drops in local circuits, controlled by polarized relays in the ground circuits.

The first semi-manual was invented by M. D. Connolly and he applied for patent Nov. 29, 1881. He merely removed the operating relay and put a drop in its place. A push button was placed on a desk in front of an attendant by means of which the arm carrying the line tripper could be moved by closing the circuit through the motor magnet. The subscriber pushed a button on his telephone which sent battery current over the line and threw the drop. The central attendant cut into the circuit, got the desired number, cut out again, pushed the button to operate the motor magnet the required number of times, and let the calling station signal the called. This left the drop of the calling line in circuit for clearing out purposes, after which the operator had to work the button to bring the line tripper to its home position.

This return to manual operation was undoubtedly caused by the recognized imperfections in the apparatus as developed up to that time.

In the short interval over which we have traced the history a number of needs had made themselves manifest to the inventors. They may be enumerated as follows:

1. Relay operation of motor magnets, the latter to be worked by battery at central. The operation of motor magnets by current which must come over the line from the substation is out of the question and entirely impractical.

2. They had begun the introduction of mechanical devices to do the work of at least part of the electromagnetic apparatus. This is shown in the abolishment of the switching relay and the private magnet.

3. Simpler movements for the subscriber. The first system had too much for him to do, resulting in too large a number of mistakes. About the only improve-

ment was in making the shifting of the pole-changer automatic.

4. A better make of relays. As then constructed, they were unduly affected by changes in line resistance. In these days (1907) it is possible to make a relay which will pull up reliably through 1,000 ohms and not stick or "freeze" when closed through a dead short circuit.

5. A busy test, to show the calling subscriber that the line called is busy. This was provided by inserting the polarized signal in the ground circuit to notify an attendant. It was not an automatic busy test.

6. An off normal indication. Switches, like all other machines, will occasionally get out of order and refuse to complete their work. Something is needed to show an attendant that some defect exists, without waiting for the subscriber to send a postal card or call in person with a gun.

7. Skilled attendance. While it may have been thought possible to make an automatic switchboard which could be set to running and allowed to take care of itself, it was demonstrated that attendance was very desirable. It will be noted that even in this day of vastly improved switches some one must be on hand to take care of the little things that go wrong even in the best of exchanges.

The above needs were felt by the early inventors, and some attempts made to fill them. That they were not successful is not their fault. It is indeed wonderful that in the short space of time they brought the development as far along as they did. But there are a few additional points which they apparently did not observe, which have been taught by the experience of the years intervening between their time and ours.

1. The great desirability of getting away from polarized relays and currents.

2. The advantage of working the whole system from one or more centrally located batteries, in place of battery at each station.

3. The answering ring from the called station was useless. It had its origin in the ancient manner of working private lines, as between a house and a store, in which the person calling always waited for the person called to ring back before taking the receiver from the hook. People's motions were slower then than now. The telephone was exceedingly new. They had not become used to its ways. If the telephone bell rang they finished their task before answering it. Now the telephone is answered before anything else.

4. The need for a better release. It is a poor expedient to make the subscriber step his switch around the rest of the circle to get home, for it takes time and brings in the possibility of added errors. The release should be positive in its action, bring the wipers or line trippers home to a fixed stop, wiping out the effects of any errors that may have occurred.

5. The use of one wire with ground return was then the accepted plan. Their switchboard was modeled consistently along this line. Metallic circuits are now known to be the only way to give satisfactory transmission of speech. This would have given them three circuits over which to select, simplifying the switching circuits. But there is a tendency in these days to return to the single circuit plan of selecting, while retaining the metallic circuit for talking purposes.

Attention should be called to the fact that the calling subscriber held the key to the release. The called subscriber could do nothing to get away from a connection till the calling subscriber released him.

IN the attempt to get rid of the difficulties incident to the use of the then imperfect magnets, T. A. Connolly brought out a switch which contained only rectilinear conductors arranged in two planes. The patent was applied for April 10, 1883, and was granted with the number 295,356. Figure 3 shows the plan of arrangement. It is novel in that it employed power drive to make the connections, also that the current impulses were made

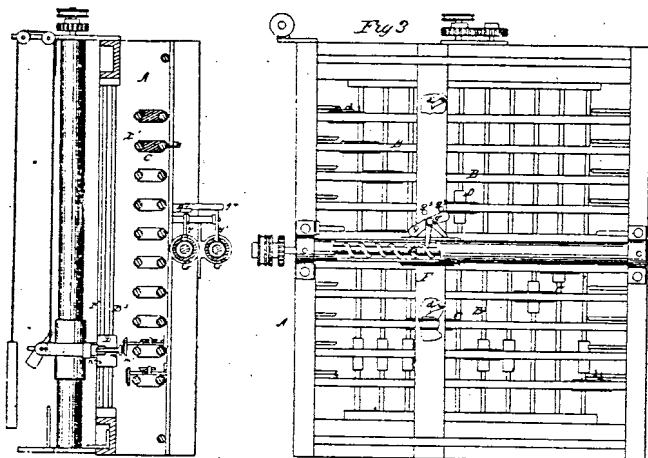


Figure 3.

and broken at central and the movement of the dial was controlled by the switch at central. B, B , etc., are horizontal bars which carry each a sliding contact block, D . There is one pair of horizontal bars for each line, and the sliding block on them is the device by means of which the line hunts up another line for connection. Behind the bars, B, B , etc., are other bars, B_2, B_3 , in pairs, each pair being connected with one outgoing line. This gives each subscriber's line a pair of horizontal bars with which to connect to other lines, and a pair of vertical bars for receiving calls. The vertical bars carry contact blocks also, which are kept always in motion, sliding up and down on the bars by a power driven sweep as indicated at the left in Figure 3. Each contact block on the horizontal bars has a cord or flat tape attached to it running to the right, over a pulley to a weight. This tends to move the block to the right, as shown in the simplified sketch, Figure 4. Attached to the shaft which carries the pulley is a notched wheel, W , a stud on the back of the armature of magnet M_1 , fitting into one of the notches, preventing the rotation of the wheel and keeping the block in its home position at the extreme left. A contact wheel, C , is also mounted on the shaft, it having as many contact bars as there are notches in the wheel, W . The brush, B^1 , carries the subscriber's line to the wheel, C , and the other brush, B , is arranged to be in contact whenever a notch is opposite the stud on the armature of M_1 . Sw_1 is an auxiliary switch connected with the block.

The subscriber's line goes from the magnet, M_1 , to the dial at the substation. Mounted on a shaft is an arm, A , which carries on its under side a spring, S , insulated from the arm. The line comes to this spring, which tends to make contact with K . The pin, P , carried by another arm on the same shaft, but insulated from it, is connected to the telephone set, T , which has apparatus for talking and ringing. The contact, K , is attached electrically to

the arm, A , which goes to the magnet, M_2 , and thence through a switch to battery and ground. In the normal condition, arm A is at zero, with P resting against S , giving us a complete circuit from T to central. To call No. 3 on the board, the arm, A , is rotated till it is opposite that number on the dial. This closes the contact between S and P . The switch, Sw_1 , is now closed, allowing current from Ba to flow through magnet M_2 , contact K , spring S , line, magnet M_1 , brush B^1 , wheel C , brush B , switch Sw_1 , to ground. This energizes M_1 , withdrawing the stud from the notch in the wheel, W . This allows the weight to pull the contact block along its rods. The stud is prevented from engaging the notches as they pass, owing to the contact of brush B , which occurs just when the notch comes opposite the stud. These impulses of current also operate the dial magnet, M_2 , causing it to let the arm carrying pin P advance one step for each pulsation of current. When P reaches S , it presses the latter away from its contact, K , breaking the circuit, and allowing magnet, M_1 , to catch and hold the wheel, W .

The contact block is now opposite the vertical bar of the line desired, and in a short interval of time the block which is moving up and down on that vertical bar will engage the block on the horizontal bar, operating switch, Sw_1 , cutting off the ground so that both lines are connected through. The ringing current was intended to be so weak or of such a nature as not to affect the magnet, M_1 .

When through talking, the calling subscriber had to

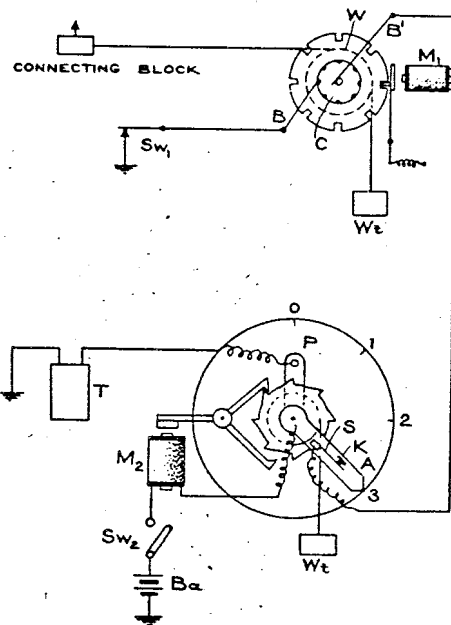


Figure 4.

operate his dial in such a manner as to move his horizontal contact block on till it reached the end of its run. There a mechanical device was automatically thrown into play, which allowed the block to be caught by the sweep, F , (Figure 3), on its next trip, and be carried by it to the extreme left, where it was held normally.

The prominent features of this system may be summarized as follows:

1. The line terminals are straight bars, parallel, carrying sliding blocks for making contact.

2. The terminal bars were divided into two groups those for originating calls, all in one plane, and those for receiving calls, which were in another plane, parallel to the first, but with the bars at right angles to the other bars.

3. Power drive was used to move the blocks in making a connection.

4. The movement of the block by the power drive made the interruptions in the current which moved the dial at the substation, and the dial determined the point

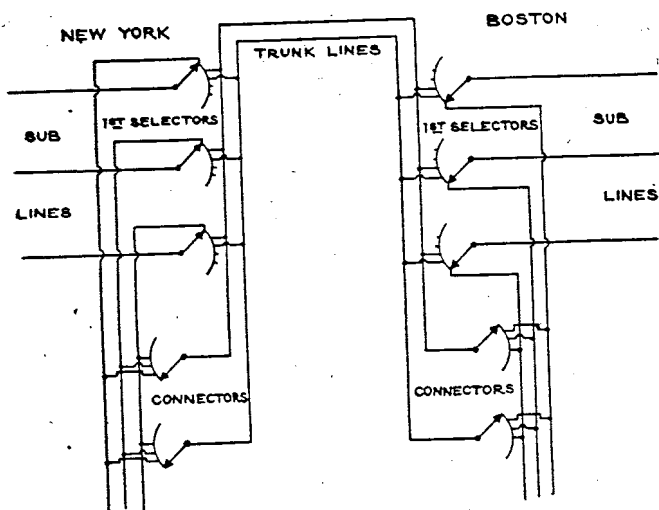


Figure 5.

at which these current impulses should cease and stop the movement of the block.

5. In releasing, the subscriber had to step his switch on to the end of its movement, but the release from that point was automatic and complete, carrying the block back to its zero position in a positive manner.

6. There were many mechanical devices employed to do electrical switching in preference to using relays.

3. Smith Automatic Telegraph Trunk Selector

November 2, 1889, there was application made for a patent on an automatic switching system for telegraph lines. The patent was later allowed under the number 481,247. This invention, though not intended for telephone use, embodies some principles which have since been improved and applied to automatic telephone switching. These principles are so important and widely used that it is well worth our time to take a brief look at the system.

The inventor was trying to cheapen the cost of giving private wire service to brokers and others who desired telegraph connection from their offices in one city to those in another city. He observed that if there were as many wires run between two cities as there were circuits leased, most of them would be in use but a comparatively short portion of the day. His idea was to provide only enough trunk lines to serve the maximum number that would be in use at any one time. Any telegraph subscriber should have access to any of the trunks, and the switching done automatically. To prevent two subscribers from getting in on the same trunk, he invented a device of very ingenious nature for hunting for the first trunk which was not busy.

The general plan is best shown in Figure 5. The subscriber lines terminated in switches, which we may call "first selectors" since they make the first selection, the picking out of a non-busy trunk. There was one first selector for each line. The trunk lines were multiplied to

the bank of contacts on each first selector, so that each line could connect with each trunk. Each trunk line terminated in a switch best known as a "connector," since it makes the final connection with the line desired. There was a connector at each end of each trunk, so that the line could be used in either direction. All the subscriber lines were multiplied to the banks of all the connectors. A detailed diagram taken from the patent specifications is shown in Figure 6. Two first selectors are shown at x and $1a$ and one connector at the right. The last is to receive calls from the other city, which is wired in a very similar manner. *Main line* refers to the trunk. Both the first selector and the connector are seen to consist of a circular bank of contacts which form a complete cylinder. There is a set of four contacts for each trunk line and a set of two contacts for the "home point" of the subscriber line to which the switch belongs. Through the center of all the selectors runs a shaft which is kept in rotation by a small motor or other source of power. Rigidly attached to the shaft is a disk, 5, in each selector. The magnet, 7, together with the wiper arms, 11, 12, and 13, and the commutator are mounted on a sleeve which fits the shaft loosely. The wipers are fixed on an arm or lever which carries a stud, 10, and an iron armature which is under the influence of the clutch magnet, 7. There is a circle of holes in the disk attached to the shaft and the stud on the arm is able to fit into any of them. It is prevented normally from doing so by the attraction of the magnet, which holds the wipers in their home position. If the magnet be released, a spring will pull the arm over, carrying the wipers away from their contact points and allowing the stud to slip into one of the holes in the disk. This clutch-like action causes the whole arrangement, magnet, arm, wipers, etc., to revolve with the shaft till an idle trunk has been found. The clutch magnet will then be energized, pulling the stud out of the hole and stopping the wipers. The same action brings the latter into contact with the springs of the trunk line selected.

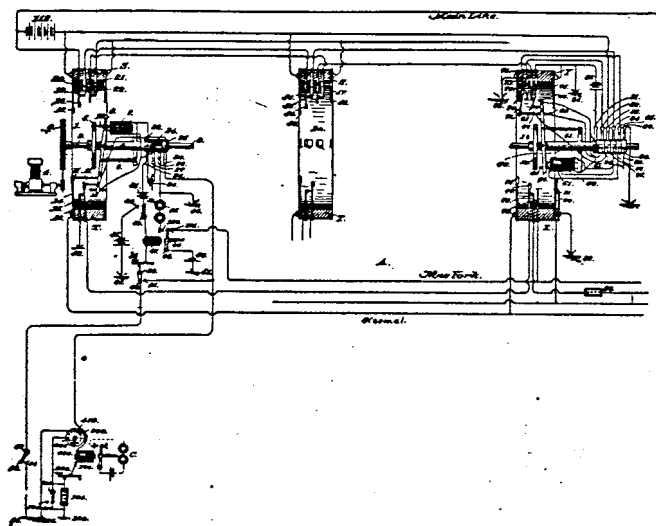


Figure 6.

Having explained the mechanism, the circuits will be more easily understood by reference to Figure 7. This is merely a schematic arrangement of the circuits with which we wish to deal. Many details have been omitted for the sake of greater clearness in the actions which interest us. The bank of contacts has been shown as if on a plane: 14 is the home point for the subscriber who uses this selector, and is connected to the "normal line" or line over which calls may be received; 17 is the contact to which is connected the trunk line shown, other lines being

connected to the like springs to the right; 22 is the busy contact and is normally connected to ground through 20. The spring, 22, is multiplied to all like springs in all the selectors which have access to this set of trunks. The ground connection is looped from 20 through all the similar contacts in all the other selectors in the group. The two wipers, 11 and 13, are under the control of the clutch magnet, 7, so that when the latter is energized the wipers are pressed upward, bringing 11 into contact with 14. When the clutch magnet is de-energized the lever moves over, carrying the wipers down, so that the lower point of 13 is in a position to wipe over 22 and all similar springs; 26 is an "off normal" switch, which is a representation of a portion of the duty of the commutator shown in the preceding figure. Its two contacts are touching only as long as the wipers are in their normal position, being broken as soon as the clutch has moved them away.

Attached to the wiper, 11, is the line, L_2 , which leads to the subscribers' instruments. It passes through a dial magnet, 102, and through resistance to ground. This dial magnet is arranged to move a wiper, 425, by a step-by-step movement. There is a circle of holes under the wiper and a plug, 430, which may be inserted into any of the holes. This plug carries ground, and is high enough to touch the wiper.

At central the clutch magnet is kept normally energized by a small battery, 30, which is closed through the off normal switch, 26. A relatively strong battery, 31, is in a second line L_1 , leading to the substation to a switch, 42, normally open.

To make a call the plug, 430, is placed in the hole corresponding to the number of the line desired at the distant city. Then the switch, 42, is closed. This allows the battery, 31, to furnish current which weakens the clutch magnet, 7, to such an extent as to cause it to let go. This carries the two wipers down and lets the stud slip into one of the holes in the disk. Since the disk is constantly revolving, it now carries the wipers with it. The first motion opens the off normal switch, 26, thus throwing the battery, 30, out of circuit. It will be seen that the continued rotation of the wipers is dependent on keeping the clutch magnet dead. Since the wiper, 13, is the terminal of the battery and magnet, if it can get connection with ground, the circuit will be completed and the magnet energized. In this simple way the wiper, 13, constitutes a "feeler," which touches spring, 22, and all similar springs on its way around the circle, hunting for a ground. Let us suppose that the first trunk is *not* busy, so that its busy spring, 22, will have ground. As soon as wiper, 13, touches 22, the clutch magnet will be energized and release the clutch, stopping the wipers. The same action pushes the wipers up, bringing 11 into contact with 17 and 13 into contact with 20. In touching 20 it is pushed away from its normal contact, 21, thereby taking ground off 22 and the other springs in other selectors corresponding thereto. The circuit for 13 is now completed to ground through 20, holding the clutch magnet, 7, energized. If, now, some other subscriber sends his selector around hunting for an idle trunk, the busy wiper will find no ground on 22, and its clutch will therefore not be pulled out. So the other wiper will be carried by this particular trunk to test and find the next one.

We are now secure in the possession of our trunk to Boston. In the connector in which our trunk terminates there are the same general features of cylindrical bank of contacts, power driven shaft, wipers, clutch magnet, etc. The clutch magnet, CM , has two windings. One of them, 62, is normally connected to ground on one side and through the off normal switch, 91, to battery and ground

on the other. In this way it is kept energized. The three wipers, 66, 69, and 68, are thus held up, so that 66 presses against spring 71. It is not in electrical contact with it. The trunk line comes through winding 61 of the clutch magnet and goes to ground through spring 71 and its contact, 70. When the wiper at New York came into contact with the trunk line at its terminal, 17, battery 112 caused current to flow as follows: From ground at Boston through winding 61 of the magnet, over the line to New York, through 112, through wiper 11, over the subscriber's line, through dial magnet 102, and through resistance to ground. This flow of current in winding 61 of the clutch magnet at Boston neutralizes the effect of the current in 62 with the result that the magnet releases and slips the clutch into action. This same motion moves the wipers 66, 68, and 69 down. Spring 71 now touches 72 instead of ground. The main line circuit is now extended from the line through winding 61, to springs 71 and 72, ending in wiper 69. As soon as the wipers begin to move under the rotary action of the shaft, the off normal switch, 91, breaks contact, putting battery 97 out of use.

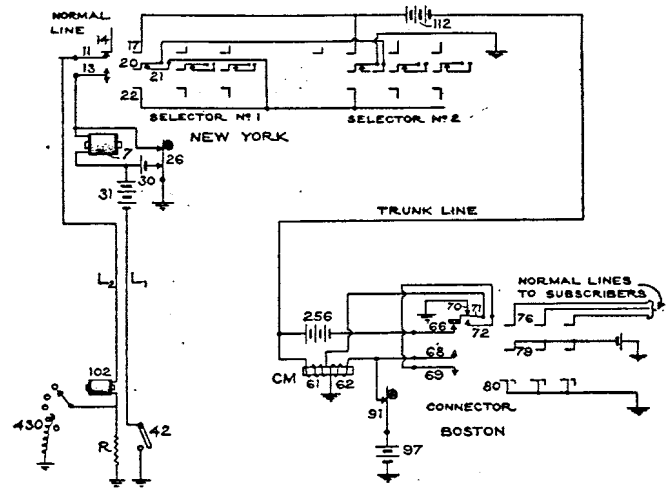


Figure 7.

Wiper 69 being down, is in a position to wipe over spring 80 and all similar ones. They are connected to ground. As the wipers proceed, this will give rise to a series of ground connections, each of which will energize the dial magnet, 102, and step the wiper around one notch for each line passed. The resistance, R , was designed to limit the flow of current to such an extent that it would not affect the clutch magnet, CM , at Boston. But when the wiper on the dial reaches the plug, 430, the resistance will be cut out and winding 61 of the clutch magnet, CM , energized. This stops the wipers at the desired line in Boston, 68 touching 79 to lock the magnet in position, while 66 touches 76 and completes the circuit to the called station. As the selector and the connector are held in position by auxiliary circuits, the main line may now be opened or closed and regular telegraphic communication carried on.

It is not my purpose to make a critical study of this invention, for we are not interested in it as a telegraphic device. But as regards the automatic switching, the following points are to be noted as of great interest:

1. A Trunking System.—The attempts at automatic switching of telephone lines which we have just studied, tried to get the maximum ratio of connections, i. e., fifty per cent. In other words, they thought it necessary to provide for the inter-connection of all the subscribers at once. This device of J. G. Smith would have given the

early inventors the right idea of automatic switching, that of only enough trunking apparatus to take care of the business. It would have required some changes to have adapted the system to telephone use.

2. The Circular Bank.—In this the system was along the most advanced lines of work of today. Numerous attempts have been made to get up a system of automatic switching employing rectilinear movements in a plane, but they have failed.

3. Power Drive.—It seems that the early difficulties of getting accurate mechanical construction in the wipers and banks of contacts were very great and gave rise to considerable friction. To overcome this and move the wipers with certainty was too much for the magnets of that day. Since then the friction of moving parts has been reduced in a remarkable degree by correct mechanical construction, and the power of magnets increased also. But there are still some who contend that power drive is the best for automatic switching.

4. Central Energy for Selecting.—As far as I know, this is the first attempt at applying strictly central battery to do all the switching. It was not common battery, for each line required its own battery.

5. Automatic Selection of Non-Busy Trunk.—This was accomplished by allowing the feeling wiper to hunt for a certain electrical condition in the contacts which it touched. This broad principle is applicable in a great variety of ways, and is very valuable.

6. Control of Dial from Central.—As we have seen, this idea is not entirely new, as the same general idea was used by Connolly & McTighe in the last board described.

Though the system possesses grave defects, it is a pity that some one did not take hold of it and remodel it into a good automatic telephone switchboard. In some points it was ahead of its time.

4. Early history of the Strowgers

Almon B. Strowger and William Dennison Strowger were brothers, born and reared in good old New York state. Both attended the common schools and the university and obtained excellent educations. A. B. Strowger was especially inclined to scholarly pursuits. But the excitement of the Civil war broke in on his studies, as it did with many others, and he served through the war as a bugler. After the war was over, he completed his education and entered the teaching profession. He had a special liking for mathematics.

W. D. Strowger became a nurseryman at Oswego, N. Y. He was much inclined to inventions, in fact, inventing seemed to be in the family. He had invented various subsoilers, ditchers, a band saw, and other things. His son, Walter S., was born at Oswego, March 3, 1863. After attending the public schools and the high school, he was sent to college at Fulton, Ill., where he took a scientific course.

On one of his vacations when he was home with his father, the two had a long talk as to what they would do when the son graduated. All along the father and son had been associated in inventive work, but this time a retrospective feeling led the father to recite his past work, his experiences, his successes and failures, and at length to enlarge upon the possibilities of the future. They talked over many things upon which they could work together. The father even suggested air ships, and finally the possibility of an automatic telephone switching device. He had no plans, but with the usual faith of inventors though it could be done. This was about 1880.

On account of ill health, Walter S. Strowger was obliged to go west for employment in the open air. In 1883 he went on a ranch in Kansas, where he worked

for three years. He settled on a farm near Eldorado and ran it for two years, after which he moved to Eldorado.

After teaching for some years, Almon B. Strowger moved to Topeka, Kan., where he engaged in underwriting. Later he removed to Kansas City, Mo. He was of a retiring nature, nervous and sensitive. In using the telephone he often suffered from the mistakes of the operators. It is not to be supposed that girls were any more careful then than now. These mistakes, delays, curt answers, negligence and interruptions annoyed him beyond measure. In his vexation, he vowed that he would do away with them. This led to his inventing the system which bears his name.

How many of the advances of life have come through the apparent thwarting of our desires! A man was once annoyed by the crying of his child. On asking the reason for the crying, his wife replied that it was a pin sticking the baby. The man made some remark about her ability to insert the pin in such a manner that it would not cause pain, and received the reply that it was impossible, for the pins *would* work loose in spite of the best pinning. His spirit was roused by the situation and he declared that he could make a pin which would not stick anyone. And he did, for he gave to the world the first safety pin.

Another man, reduced to such poverty that his wife had to take in sewing, sat one day in their poor attic watching her nimble fingers as they deftly passed the needle in and out through the goods. The thought of the purely mechanical nature of the operation struck him forcibly, and he wondered if a machine could be made to do the work. But he did not stop with the mere wonder, for he went to work with such energy that he succeeded in finishing a machine which not only would sew, but did it faster and better than could be done by hand.

If the baby had not cried at the right time, the safety pin might not have been invented as it was. If Elias Howe had been in comfortable circumstances, he might not have been led to study sewing and bring out the sewing machine. If the telephone operators had been quick and sure, and polite, or if Mr. Strowger had been one of those good natured men whom nothing angers, he probably would never have turned his attention to the automatic telephone.

A. B. Strowger's determination to do away with manual operators started him to active work and his ideas took tangible form in an application for patent on his system, which he filed March 12, 1889. Shortly after this, his nephew, Walter, came to visit him at Kansas City, Mo. He told Walter of his trouble with the operators and that he was then working on the design of an automatic switch to do away with them. To illustrate his idea he walked into the bedroom, picked up a collar box, and with it he showed how he proposed to arrange the terminals in rows on the inner surface of a cylinder. He explained that some sort of an arm would be arranged to swing on a shaft and be able to come into contact with any of the terminal wires. After talking over the matter for some time, he asked Walter to work with him in developing the invention. The nephew was about twenty-six years old at this time, full of energy and willing to work. He readily consented, and from that time on he lived at his uncle's house.

The first thing to be done was to begin the construction of a model according to the best ideas which they had at that time. They expected that difficulties would develop, and that the only way to find them was by actual construction. Realizing that the switch would doubtless call for exact construction, they went to Wichita and hired

a jeweler and helper at \$5.00 each per day to make the first model.

Of the trials of these early days it is difficult for us to get an adequate conception. It would be supposed that above all other men jewelers would be able to put up exact and true construction, to make all the parts so that they would operate like clockwork, with ease and certainty. It is very likely that they could have done so, but they did not. They had no faith in the project, their heart was not in their work. One of the early writers has said that "Without faith it is impossible to please God," and we may add that without faith it is impossible to do any great and lasting work. But with faith in the outcome, with his heart in the work, a man can do almost the impossible.

Although Almon B. Strowger was the inventive genius who devised the circuits and mechanical parts, a great part of the responsibility for getting those ideas reproduced in wood and metal fell on his nephew, Walter. Many a night the latter worked till midnight planning the work for the next day, so that the workmen could proceed along the lines laid down by the inventor. It seemed almost impossible to get the workmen to get the idea or to construct the machine with sufficient accuracy. A. B. Strowger's retiring nature shrank from the struggle and often gave vent to the words, "We can't get them to do it!" But what the older man lacked in courage the nephew made up, and threw his whole energy into the task. Walter's mother also stood by him and always encouraged him to go ahead and make it a success.

There were those among the friends of both men who enjoyed throwing cold water on the whole business. One of them told Walter Strowger that he had better go and hire out to a farmer, as he would make a better success and more money. N. F. Frazier, a man of considerable means, living in Eldorado, proved himself a great friend during these times. He loaned them money and encouraged them in their work. During the first two years of the development Walter S. Strowger sold everything that he had in the way of property, sometimes getting only a quarter of the value of it. Upon this money and that generously advanced by Mr. Frazier the first two years' work was done.

Joseph Harris was at that time a traveling clothing salesman. Having a brother-in-law in Eldorado, he used occasionally to stop there. It was known locally that W. S. Strowger was working on an automatic telephone system and Mr. Harris heard of it.

Thinking this would make a good investment, Mr. Harris approached W. S. Strowger and offered to make a contract for the idea. Mr. Strowger did not act on the offer, but told Mr. Harris to wait till the model was completed.

In working out the circuits for operating the switch which he had invented, A. B. Strowger attacked the problem from an entirely new point of view, which it is well for us to understand clearly. Preceding attempts at the construction of automatic systems had clung to the single wire idea, trying to operate all sorts of mechanisms and electrical apparatus over one wire with ground return. Mr. Strowger proposed in his first machine to use as many wires as he needed and thus get it to operating. Then he would try to reduce the number of wires as rapidly as possible, not attempting to sacrifice simplicity and certainty for a small number of wires.

5. First Strowger automatic switch

THE essentials of A. B. Strowger's first automatic switch are shown in Figure 8. The terminals of all the lines in the exchange were brought to rows on the inside of the cylinder, *A*. There were planned to be ten rows of 100 terminals each, giving a total capacity of 1,000 lines. *aa* represents the terminals and *B* the lines. In the axis of the cylinder a shaft *D* was arranged, capable of both vertical and rotary motion. This shaft carried an arm, *C*, which was the wiper to make contact with the line terminals. In the first machine made the cylinder was wood and the terminals were brass escutcheon pins. The vertical motion was secured by the step by step action of a magnet, *KV*, which had a pawl on the end of its lever. Another pawl was provided to hold the shaft during the return stroke of the magnet.

There were two rotary magnets. One of them, *KR1*, was capable of rotating the wiper past ten terminals at a step. The other, *KR2*, could rotate the wiper only one terminal per step. In this way the vertical motion selected the hundred, the rotary motion of ten notches at a jump selected the ten, and the last rotary motion of single notches selected the unit. Mounted on or near each magnet lever was another magnet adapted to release the mechanism by pulling the pawl out of the tooth in which it was resting.

Figure 9 gives a general view of the machine and its circuits. At the left is the subscriber's instrument, with the battery for operating the magnets of the switch.

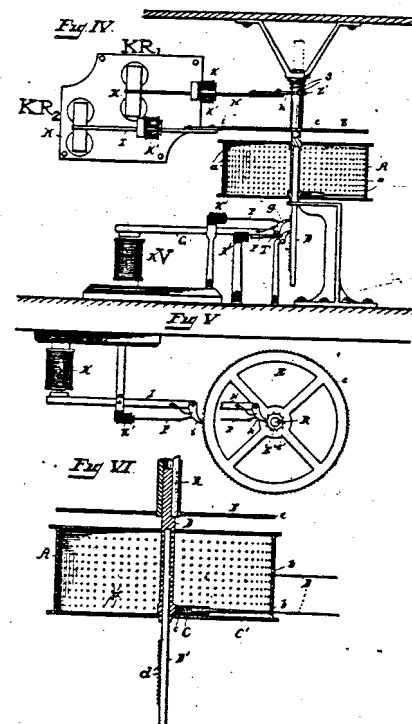


Figure 8.

Four push buttons were on the telephone box, each button controlling a wire, while the fifth wire was for talking. Each of the four wires had but one function, in striking contrast with previous systems which we have examined. Thus the vertical wire ran from the button on the telephone marked *G'* to the vertical magnet on

the switch. The two rotary wires, R_1 and R_2 , run from buttons H' and I' to their respective magnets, KR_1 and KR_2 . The release line, R_0 , runs from button P' to the switch and loops in series all the release magnets. All

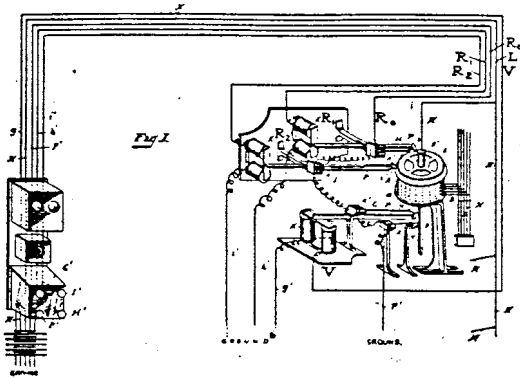


Figure 9.

these lines after passing through their magnets in the switch terminate at ground. The fifth or talking wire goes from the talking set in the telephone to the wiper in the switch, also to the proper line terminal in all the cylinders of other switches in the office.

The operation was as follows: Suppose that the number desired was 345. The subscriber would push the G' button three times, thereby lifting the shaft three notches and bringing the wiper opposite the third row of terminals. He would then press the H' button four times, which would rotate the shaft and wiper four times ten notches. Pressing the I' button five times would rotate the wiper five more spaces, thus arriving at 345. The ringing of the called subscriber was done with a magneto or battery. When through talking, the button P' was pressed, which energized all the release magnets at once, allowing gravity and a spring to return the shaft and wiper to their normal or zero position.

A number of points of interest are prominent in this machine, and I shall briefly mention them.

1. The arrangement of the contacts in rows on a curved surface. This has become almost standard. It may be regarded as very fundamental.

2. The wiper rubbing over the contacts in succession.

3. Vertical and rotary motion. For many years this has been regarded as the ideal action, but some are coming to regard a simple rotary motion as better. In the attempt to get away from the mechanical complications of the vertical and rotary motions, some very complicated electrical circuits have been evolved. But it is to be hoped that these circuits may be simplified.

4. Rotary motion in jumps of ten for the tens, followed by single jumps for the units. This action has no very good ground for being, and has been abandoned by all who have tried it.

5. Complete release to zero or initial position. This is the first switch in which the release was at all satisfactory. When the release button was pressed, the user had the satisfaction of knowing that all his mistakes had been wiped out.

6. Five wires and ground. This was excessive, but in the plans of the inventor he was to reduce the number. As stated before, he intended to take as many wires as he needed to work the switch and then reduce them by careful experiment.

7. Local battery. This was a very bad feature. It is not clear why all these magnets could not have been operated by battery in the ground wire at central as well as in the ground wire at the substation.

8. Calling subscriber controlled the release. This is still the case in some modern automatics, but is receiving attention.

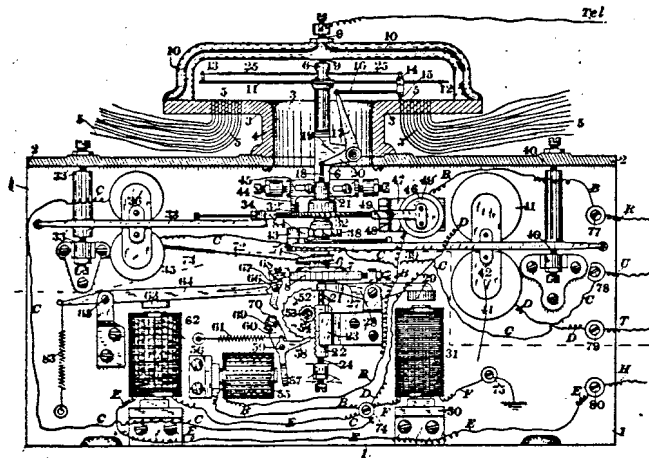


Figure 10.

9. No privacy. Any one could get in on a connection by intention, or accident. Also it will be noticed that in selecting a number, the wiper actually connected the telephone to all the lines lying in the path over which the wiper moved, though it might be but for an instant.

Some time in the year 1890 the first model was completed. It was set up and exhibited in the office of the Kansas & Missouri Telephone Company (Bell). Its operation, though in a crude state, was satisfactory enough to show its possibilities. The local manager of the Bell Company was very much interested and impressed. He mentioned to the Strowgers the possibility of selling the invention to the Bell Company, and said that he was willing to get them an audience with the company if they wished. But he advised them to develop it before trying to sell, as in its present shape they would have to take the company's terms. He said further that telephone switchboards ought to have been automatic from the start. Manual was only a makeshift and there was in his opinion no question about the future of the automatic. It was only a question of time and money to perfect it.

During this time the matter of the patent had been dragging along in the hands of a lawyer. Seemingly it was too slow in being allowed. Finally the lawyer informed the Strowgers that it had been allowed. Later they found that it was not true, and that the matter was in a very much mixed up state. When the patent authorities asked questions, the attorney attempted to answer them himself, without referring it to the inventors. Not being an electrical expert, he got things badly mixed up. When this state of affairs was discovered, the Strowgers took matters into their own hands, and dealt with the patent office directly. They succeeded in straightening out the errors and had the satisfaction of having it allowed within six months after they took it up themselves.

6. Exhibiting the system

Joseph Harris and M. A. Meyer now urged A. B. Strowger to come to Chicago and set up his machine. Mr. Harris was connected with the World's Fair, which was at that time scheduled to be held in 1902. He told

1892

Mr. Strowger that on account of its position Chicago was a much better place to work. There were people from all parts of the country and the world and there was an excellent chance to get them interested in the invention. Both Harris and Meyer wanted to contract with the Strowgers, but offered to pay all expenses of the Chicago venture even if they failed to make the agreement.

In the fall of 1890, A. B. and W. S. Strowger agreed to come to Chicago and exhibit their invention. This they did in the early winter. The next day after arrival in Chicago the four men signed up a contract. According to the terms, each of the Strowgers was to receive a certain sum and a salary and an interest in a stock company which was to be formed later. The plan of operation was to raise money to carry on the further experiments developing the invention, and then to put the system on the market. From the date of the contract Harris and Meyer began an active canvass for the money for pushing the work.

In the meanwhile the inventors were busy setting up the model which had been completed and operated at Kansas City. Mr. Harris had an office in the Rookery building and here the exhibit was wired up. A lineman from the Chicago Telephone Company was secured to help wire. This lineman had a friend by the name of Frank Lundquist, who was visiting in the city at that time. Mr. Lundquist was also a lineman and came along to help with the work. He became greatly interested in the idea of an automatic switch.

There were many visitors to see the new wonder, and among them was the ever present newspaper reporter. There were a few paid write-ups of the usual order which attracted the attention of the people of the city. But there were occasionally humorous attacks by the papers, trying to discredit the invention by holding it up to ridicule. One of them said, "What is the use of these plebeians coming here to do what Bell, Berliner, and Edison failed to do?" Indeed, the staid electrical lights of Chicago looked on it as presumptuous in these inhabitants of wild and woolly Kansas to attempt what they were attempting. But the whiskery new-comers had been working on the problem too long not to know their ground, and were more fitted to speak on the subject than their critics.

There were many visitors from abroad, Germany,

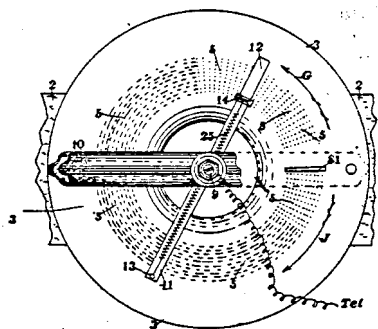


Figure 11.

France, and other European countries. The general public looked on it as a very hard problem. But these electrical men from abroad said that the idea was all right and expressed their faith in its ultimate success.

The patent which had been applied for when in Kansas City was formally issued March 10, 1901, under the number 447,918.

Owing to imperfections in the first machine it was thought advisable to change the form somewhat. It seemed that it was very difficult to make the cylinder, shaft, and wiper accurate enough to be sure of always hitting the proper terminal. The margin of error allowable was too small, or the actual variation of the moving parts too great, for the wiper would not act with certainty. Thinking that it would be easier to secure accuracy on a plane surface, the bank of terminals was changed to a flat disc. The line terminals were arranged in circles around the center, with the same number in each circle. It was first planned to have but one circular row of 100 terminals. The wiper was mounted on a shaft which was run through the disc at right angles to its plane. Having but one motion, the machine was very much simpler, though its capacity was only 100 lines.

Having worked out the design of the new switch, of which there is unfortunately no illustration at hand, the Western Electric Company was asked to estimate and bid on its construction. This company had been friendly to the extent of selling the experimenters anything they wanted. When the company sent over their expert to figure on the job, W. S. Strowger was left to explain what was wanted. Mr. Strowger explained the limitations, and how closely the parts must work. After listening to all of Mr. Strowger's conditions, the expert remarked:

"What do you want such fine, chronometer work for? You might as well keep the girls as to have such fine machines."

Mr. Strowger replied:

"Do you want to bid on the job?"

"Yes," was the answer.

The Western Electric Company at this time stood as a company against the automatic idea, and stood back from participation. But individually the Western Electric people were very kind and accommodating.

The job of constructing the new machines was finally let to the Union Model Works, which was run by Mr. Brown on Clark street, about half a block north of the present postoffice building. There were twenty machines made at a cost of \$60 each. W. S. Strowger had gone into the matter of costs and made the prediction that if made in their own factory under his supervision the cost could be reduced to \$5.00 per switch. It took three years to reduce it to that point.

In accordance with the contract, the automatic company was incorporated October 30, 1891, under the name "Strowger Automatic Telephone Exchange." The incorporators were as follows: M. A. Meyer, president;

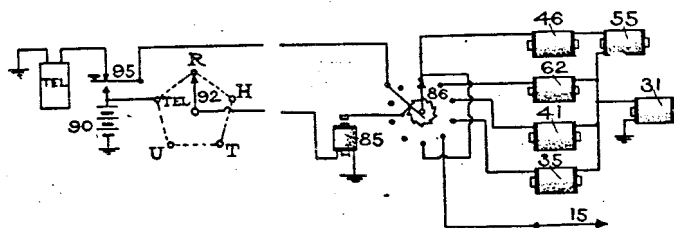


Figure 12.

A. B. Strowger, vice-president; Joseph Harris, secretary; W. S. Strowger.

The capacity of the flat disk switch was now increased by giving it ten circular rows of 100 terminals each. The principles involved are clearly shown in the patent which was afterward applied for (February 19, 1892). A general idea may be obtained from Figures 10 and 11, the former being a vertical section and the

latter the plan. In Figure 10, 3 is the table or rubber disc upon which the line terminals, 5, are mounted. The vertical shaft carries a radial arm, 12, on which slides the wiper proper, 15. By a very ingenious mechanical arrangement the magnet, 62, can move this wiper out along the arm from row to row, thus enabling it to select

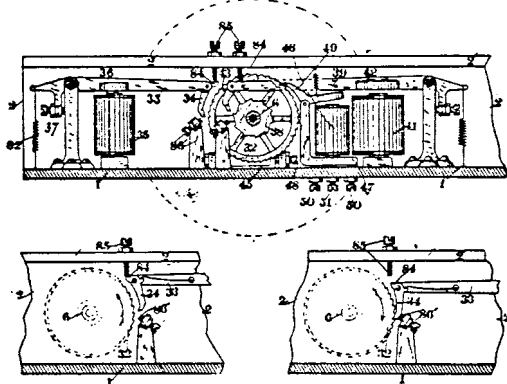


Figure 13.

any hundred. The rotary motion is given by two magnets, as in the first machine. Magnet 41 rotates the wiper by jumps of ten, while magnet 35 makes single steps. In this way the hundreds are selected by magnet 62, tens by magnet 41, and units by magnet 35. The release is accomplished by two magnets, 46 and 55, which release the rotary and radial motions respectively. The principles of the release are identical with those of the first machine, namely, the pulling out of the pawls which hold the advance motion, allowing the springs to pull the moving parts back to their zero position.

To avoid the friction which had been found to be quite a source of trouble heretofore, a peculiar mechanical action was employed in making the wiper shaft jump up and down for each movement, radial or rotary, which the wiper made. This was secured by putting another magnet at the bottom of the shaft with its armature arranged to lift it. The winding of this magnet was cut in series with all the working magnets, so that with the working of any of them the "jumping" magnet would work.

Figure 12 shows the plan of circuits from one telephone. At the left, *Tel* is the telephone, which may be of any variety. 95 is a strap key which is used to make the magnets work. A dial switch was devised to work in connection with a magnetically operated switch at central for controlling the impulses which were sent in over the upper line wire.

This dial switch has five contacts, marked *R*, *H*, *T*, *U*, and *Tel*. All the points are tied together to battery, 90. The lever of the switch, 92, was attached to the lower line wire and at central went to ground through the magnet, 85. This magnet was capable of acting with a ratchet on another switch whose wiper, 86, was adapted to move into contact with any one of ten terminals. The upper one of these terminals was wired to the two release magnets, 46 and 55 and to ground through the "jumping magnet," 31.

The second point on the switch, 86, ran to the magnet, 62, which made the radial movement of the wiper. The third point connected to the magnet, 41, which rotated the wiper by jumps of ten, while the fourth point went to the magnet, 35, which made the single steps. The fifth point ran to the wiper itself, 15, and was for talking purposes; it constituted the cord circuit or rather the connecting plug.

In this way the switch, 86, acted as a distributor for the impulses, directing them to the proper magnet at the right time. Suppose it were desired to call 234. The switch at the substation, 92, would be turned to the point marked *H*. This sent one impulse over the low line wire, advancing the switch, 86, one notch, bringing

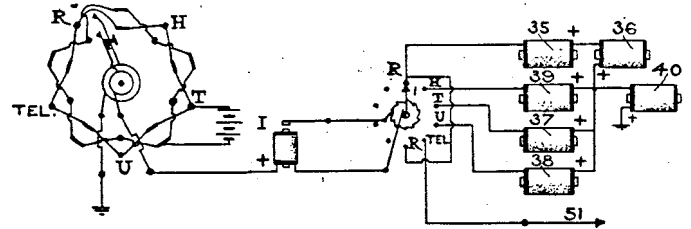


Figure 14.

the upper line wire into connection with the hundreds magnet, 62. Then the key, 95, would be pressed twice, energizing both 62 and 31, making two jumps upward and outward with the wiper, 15. Then the switch, 92, would be turned to the point marked *T*, which shifted the connection of the upper line wire from the radial magnet to the tens magnet, that is, 41. Key 95 would now be pressed three times to move the wiper in a rotary direction three times ten notches. In this way the units were also selected, finally switching the upper line wire onto the wiper itself for ringing up the called station and talking. There were ten terminals on the switch 86, with opposite ones tied together. In this way the switch had to move through only a half circle in making one call and releasing.

One of the mechanical devices to which I would like to call attention is shown in Figure 13. In the upper half of the figure is shown the exact manner in which the tens and units magnets were arranged, together with the release magnet for the rotary. At the lower left hand is shown a special ratchet construction which was designed to prevent the inertia of the moving parts from carrying them farther than intended. As the movements of an electromagnet are very quick, there was danger of giving the shaft a sudden kick, and the momentum carrying it past the point. This was obviated by providing a set screw, 86, which held the pawl firmly against the wheel, 32, as long as the magnet was energized. This gave a locking action to the ratchet which was very effective. The sketch in the lower right hand corner shows the ratchet pulled up in locking position. Another neat point of ratchet construction was the set screw, 85, which prevented the pawl from touching the wheel when the pawl was in its normal position. The spring, 33, tended to keep the pawl against the wheel, but when the magnet lever moved back, the back end of the pawl hit the set screw and moved the point out of contact with the wheel. The advantage of this is most apparent in connection with the release making it unnecessary to have any release magnet to pull this pawl away.

We may now review the salient features of the system as follows:

1. The flat disc construction.
2. The lifting action to avoid friction at the contacts. This seems to have been the great bugaboo of all the early inventors.
3. The reduction to two line wires. One of these, the upper in Figure 12, was the impulse or step-by-step wire, and may be roughly likened to the vertical wire of recent systems. The other, the lower line wire in the same figure, was the controlling or directing wire,

determining what magnets the other wire should act upon. It may be likened to the rotary wire in modern practice. But it must not be forgotten that the upper wire was also the talking wire, with ground return.

4. The special switch at central for distributing the impulses of the upper line wire. This may in many respects be called the "side switch," as it acts like the side switch of modern connectors. The magnet which operated it might be called the "private magnet," though it has no protective action in this case. There is one fault which we must find with the "side switch" in that its correct action, indeed the correct operation of the entire machine depended on the "side switch" keeping in perfect step with the dial switch, 92, at the substation. If by any means they got even one notch out of step, it would result in dire confusion to the subscriber. And the latter had no means of correcting it.

5. There was no privacy provided. Any person could get connection with any other line, no matter if it were already connected with another.

6. The locking device on the ratchets. This is a very good point, and is still used on some of the best machines.

7. The aim seemed still to be to get the maximum number of stations connected at any time, by providing each with a switch. The percentage idea had not yet been applied.

This patent was issued November 29, 1892, with the number 486,909.

The effort to reduce the number of line wires led the Strowgers to attempt to use polarized magnets in connection with the flat disc machine which has just been described. On the same day, February 19, 1892, they applied for a patent on their single wire system, which was later granted and issued as No. 492,850. Without repeating the details of the former machine, Figure 14 shows the way in which the selecting was accomplished over one wire. All the magnets were made polarized, so that each required current to enter at the terminal marked "+" to work it. Current in the opposite direction would have no effect on it. These magnets are as follows:

- I=magnet of side switch,
- 35=rotary release magnet,
- 36=radial release magnet,
- 39=hundreds magnet,
- 37=tens magnet,
- 38=units magnet,
- 40="jumping magnet."

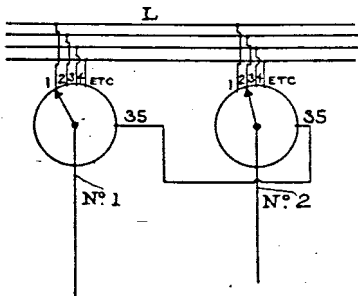


Figure 15.

The magnet, *I*, of the side switch was the only one which worked on current coming in over the line, all the others requiring current to flow up from the ground.

At the substation the dial was arranged in the form of two concentric rows of contacts. Those marked with

a round symbol are short enough not to be touched by the two wipers, 5, unless they are pressed intentionally against the contacts. The other contacts, shown by long marks, are high enough so that in turning the wipers, 5, around they will always touch. One of the wipers, 5, is attached to ground and the other to line. The battery is attached to the two rows of contacts, all the short pins having negative battery on the outside, while the long pins have positive on the outside.

Normally the lever, 5, of the dial was intended to be kept between the two pins marked *R* and the long pins at the top. To call 234, merely move the arm, 5, over to *H* and press it two times into contact with the short pins. Then move it to the *T* pins and tap three times, then to the *U* point, and tap four times, finally to the *Tel* point and press once. To release, turn to the pins marked *R* and press once.

The operation of pressing the lever, 5, down on the short contact pins had the effect of sending impulses of negative current over the line, which operated whichever magnet was at that time in connection with the line through the side switch. But it had no effect on the magnet of the side switch. When the lever was moved from one short pin to the next, the wipers were automatically made to touch the long pins, thereby sending an impulse of positive current over the line, which operated the magnet of the side switch and shifted the circuit to the next magnet.

It is unnecessary to comment on the undesirability of bringing back the use of polarized magnets. As far as known this board was never used.

Early in the year 1892 the Brush Electric Company of Baltimore sent Mr. A. E. Keith to investigate the merits of the Strowger automatic telephone system. After a thorough study of it, Mr. Keith was so favorably impressed with its possibilities that he entered the employ of the Strowger Automatic Telephone Exchange soon after. Being a practical man, expert in factory work, his coming was a valuable addition to the forces engaged in so great a task.

The fact that the automatic system as thus far developed was not private was a great hindrance to the prospective investor and to the public in general. The financial promoters met the objection by the statement that the system had been made secret, and then called on the inventors to make it good. This Mr. W. S. Strowger did in a way which satisfied the need of the moment. Figure 15 shows the principle. *L* are the wires which connect the line terminals of all the switches together. He made the wiper of line No. 1 to rest normally on a "home" contact, as did No. 2 and all the others. Under ordinary conditions, when No. 1 moved his wiper around to talk with No. 2 they were safe from interruption by calls which might come in by any one else trying to call No. 1. The third party would find the home point of No. 1 open. But if he called No. 2, who is the called party in the connection, the third person could get in on the line. To make it entirely private, Mr. Strowger provided between each two subscriber's switches a private line, terminating on the same number on each switch, as for instance, No. 35. Then if the two men wished to converse without interruption, they would agree to shift their switches simultaneously to No. 35. As this line appeared on their two switches only, no one else could connect with them. That this was wasteful of space in the terminal bank is apparent, but it met the need for the time being.

About this time a company was organized in Canada for the purpose of pushing the automatic telephone in

that territory. But there is no record of their having done anything.

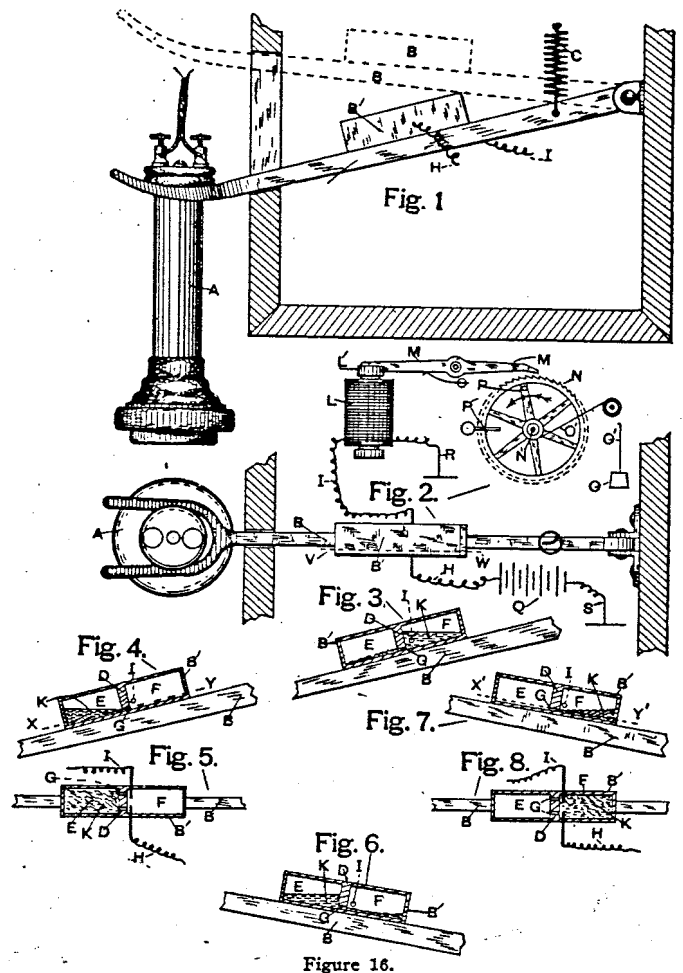
The twenty machines which had been made by the Union Model Works were now put into service as exhibits in various cities. At all the places where it was shown, and all over the country, it roused great interest. As usual, people took sides, some declaring it a foolish and impossible scheme, others seeing its possibilities and wanting to buy it up. One of the practical results of these exhibits was the discovery that when the common public used the apparatus, they got electric shocks at times. Inquiry showed that these shocks came through the exposed binding posts on the receivers, which were of the ordinary Bell type which was then the standard. This led to the adoption of a type of receiver which had the binding posts concealed in the inside of the shell.

In the fall of 1892 W. S. Strowger went west to California to exhibit the system and raise money for its development. He exhibited in both San Francisco and Los Angeles. At the latter place, he was approached by a man who offered to buy out the whole invention. He proposed to get up a syndicate and trade Los Angeles real estate at full value for the automatic stock at quarter value. Mr. Strowger refused to deal with the man. He was afraid that if the automatic got into the wrong hands, the whole thing might fail. Since that time the real estate which was offered for trade has advanced till it is now worth several millions of dollars.

The spring of 1893 Mr. Strowger returned to Chicago.

8. The first public system

THE object of the exhibits which the automatic people had been making in various cities was for the purpose of enlisting capital, and as well to secure some place where the system could be tried out by the public. Finally a contract was secured for a plant to be installed



at LaPorte, Ind. This has the honor of being the first automatic exchange in public service. In May, 1892, Mr. A. E. Keith began its installation. The switch used was the flat rubber disk type which has been described. It had but one movement for the wiper and one circular row of contacts. This limited its capacity to 100 lines. The wiper was carried on an arm which lifted while rotating to avoid the friction on the contacts, which would otherwise have impeded its movement. This was accomplished by the "jumping magnet" which was described in the December issue. The tens were selected by jumps of ten notches each and the units by single notch movements. The board was opened to public use November 3, 1892.

This was the first time that the Strowger system had been actually used for commercial purposes by the general public. That it was successful in a certain way and was favorably received by the public is shown by the letters written by the users.

But it began to be noticed that occasionally a switch failed to release entirely. This was found to be due to the slowness with which the switch returned to its initial position. The ordinary subscriber would press the release

button as long as he thought necessary, and if his call had been for a low number there would be time for complete release. But if a high number had been called the wiper arm was drawn almost around the circle. It would therefore require a longer time in which to swing back to the zero point. Of this fact the subscriber had no knowledge, or if he did it was impossible to get all people to observe it and hold the release button longer for a high number than for a low one. Uniformity of operations is one of the fundamentals of a good telephone system, especially an automatic.

To remedy this deficiency Mr. Keith, in the spring of 1893, invented an automatic release attached to the hook lever on which the receiver was normally hanging. Placing it in this position made it unnecessary for the subscriber to pay any attention to the release.

Figure 16 shows the details of this device. A small box having two compartments was attached to the lever of the hook. In the lower portion of the partition were two small holes. Just over the holes and in the compartment nearest the pivot of the lever were two terminals fixed. One of these was attached to battery and the other to the release line. In either compartment was a suitable quantity of mercury.

In the normal position, the receiver on the hook, the left-hand space was lowest and would contain all the mercury. When the receiver was lifted from the hook to begin the conversation the mercury would gradually run out through the two holes into the right compartment. In so doing it would not touch the release wires. When the receiver was hung on the hook at the end of the conversation the lever was again tilted downward, causing all the mercury in the right compartment to flow downward and cover the release wires, while gradually escaping to the other compartment. This held the release

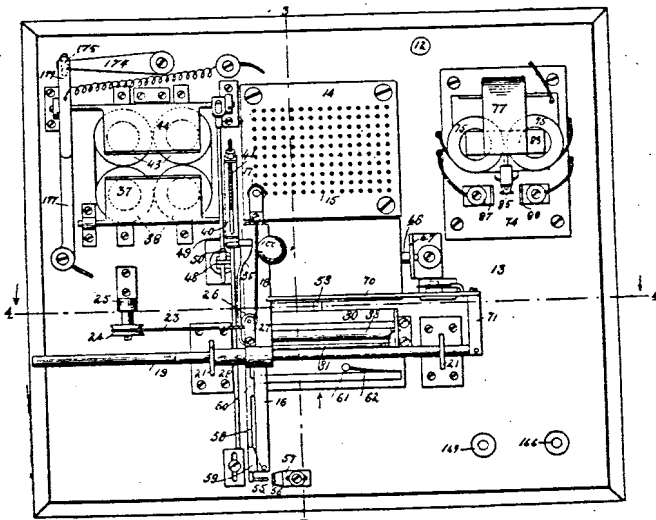


Figure 17.

closed for an ample time. It was known as the "pill box release." The patent was applied for on this device September 16, 1893, and was issued December 29, 1896, Number 573,884.

The automatic system was exhibited at the World's Fair all during the summer of 1893 and attracted a great deal of attention. Engineers and scientists, especially those from abroad, seemed to be greatly impressed with the desirability of automatic switching and with the merits of this particular system.

During the year 1893 Mr. T. C. Martin came into the employ of the Strowger Automatic Telephone Exchange as an engineer.

W. S. Strowger, who had returned from California, was sent to install a small system in Fort Sheridan, Ill., for the United States government. The switch was the same flat type as had been installed at LaPorte, Ind., mak-

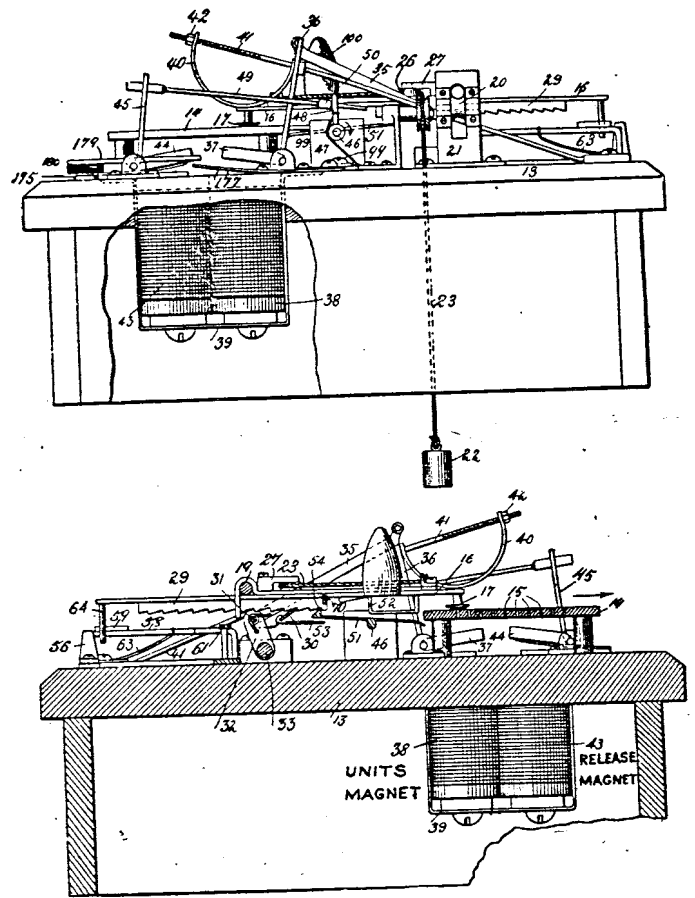


Figure 18.

ing the rotations by lifts and jumps. Some trouble was experienced owing to dust which lodged on the contacts. As the wiper jumped up and down and did not actually wipe across the terminals, occasionally the dust would prevent proper contact and the wiper could not clear itself. The system was finished in October, 1893.

About this time was the beginning of the famous panic of 1893. People must have groceries and clothing, but expensive luxuries like automatic telephones could be dispensed with. This was especially true of the investor, whose aid was so necessary in developing the automatic system. Money became "tight," with the result that it became exceedingly hard to keep things going, and all new ventures like the automatic telephone were in danger of going to the wall. However, by proper measures the automatic business was piloted through the storm.

9. The Erickson System and Lundquist

Frank Lundquist and the Erickson brothers (John and Charles J.) had been boys together in Kansas. The latter lived on a farm near Lindsborg. The Ericksons were born experimenters. Nothing suited them better than to get hold of some paper like the *Scientific American* and read all through the many inventions that were

continually being brought forth, then to try to make the things which seemed the most interesting to them. They made all kinds of electrical instruments—coils, bells, magnets, medical coils, etc. They had been working on a printing telegraph and had even started the construction of an electric pianola or piano player. Reading of the invention of Bell, they at once made several telephone receivers which talked. Lacking battery for their experiments, they hunted up the proper materials and made it. Being at a great distance from good supply centers like Chicago and New York made it difficult for them to get many of the supplies which they needed. They bought bare copper wire and insulated it on a home-made machine.

In the meantime Frank Lundquist had gone out into the world and had received his introduction to the automatic telephone at Chicago. In the fall of 1892 he returned to Lindsborg, Kansas, and induced the Erickson brothers to take up the invention of a better automatic than the Strowger. This was a greater work than any which they had yet attempted. Before that, to use their own words, they had only worked on "foolish things," but now they had a problem worthy of their genius.

But their earlier activities were not altogether "foolish things," for all their experiments with bells, batteries, telephone receivers, etc., had taught them in a practical way the nature of electricity and how to handle it. It was a training which was very necessary in view of the scarcity of good writings on the subject.

So when a boy spends all his spare time tinkering with all kinds of mechanical or electrical things, don't harshly drive him away from his beloved pursuits. Observe what results he gets, provide suitable time for such employment, and give him a chance to develop.

Realizing that the work of the development of an automatic system would require considerable money, Mr. Lundquist induced John and Gus Anderson, of Lindsborg, to furnish the funds. Little by little they advanced money till between them several thousand dollars had been furnished.

The three men working together evolved two switching systems which resembled each other in the main, the second being an enlargement and improvement of the first.

The first system is shown in Figures 17, 18, 19 and 20. Figure 17 shows the plan of the switch. The line terminals, 15, are arranged in ten rows of ten each on a flat, rectangular surface. The wiper, 17, is on the end of an arm, 16, which is carried by a carriage, 18. The

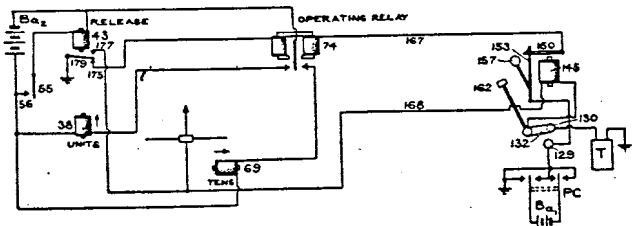


Figure 19.

latter is mounted on a rod, 19, which can move to the right, longitudinally. The arm, 16, can move upward, transversely, by sliding in the carriage, 18. This action is shown by Figure 18, which presents two end elevations, the upper one being from the left and the lower from the right side. A magnet, not shown in the figures, is adapted to move the rod, 19, longitudinally, to select the tens. Magnet 38 moves the wiper arm, 16, transversely to select the units. A single cord, 23, and weight, 22, tends to draw the wiper and rod back to the zero point.

The release magnet, 43, unlatches both ratchets, allowing weight 22 to pull wiper 17 back to the zero position. The circuit feeding current to the release magnet is controlled by two contact points, 55 and 56. If the wiper, 17, be moved out transversely one space beyond the upper row of terminals, the points 55 and 56 will be closed, bringing the release magnet into play. The contact points will not be opened till the zero point is reached.

Figure 19 shows the general wiring of one switch and sub-station. The various parts have the same designations as in the preceding figures. There are two wires to the sub-station, the operating wire, 167, and the talking wire, 168. Wire 167 runs from a polarized operating relay, 74, to the latch, 150, of the magnet, 145. From there it goes through a weighted shutter, 153, to a pole-changing switch, PC. 132 in a switch which is provided with an arm and insulated end piece, 162, adapted to come into mechanical contact with the shutter, 153, when the switch, 132, is on its lower contact, 129. The switch, 132, will stay in either position.

The operation is as follows: With the switch, 132, on its upper contact, 130, the subscriber pushes the pole-changer, PC, as many times to the right as there are tens in the desired number. This sends that many impulses of positive current over the line, 167, to the operating relay, 74, causing it to swing to the right and operate the tens magnet. This moves the wiper, 17, longitudinally to the right to the proper tens row. The subscriber then pushes the pole-changer, PC, as many times to the left as there are units in the number. This sends negative impulses over the line, making the armature of the operating relay, 74, swing to the left, operating the units magnet. The latter moves the wiper, 17, up to the desired unit; that is, to the terminal of the called line. From the telephone, T, any kind of signalling current is sent to call the distant station, the ringing current passing through magnet 145 but not necessarily operating it.

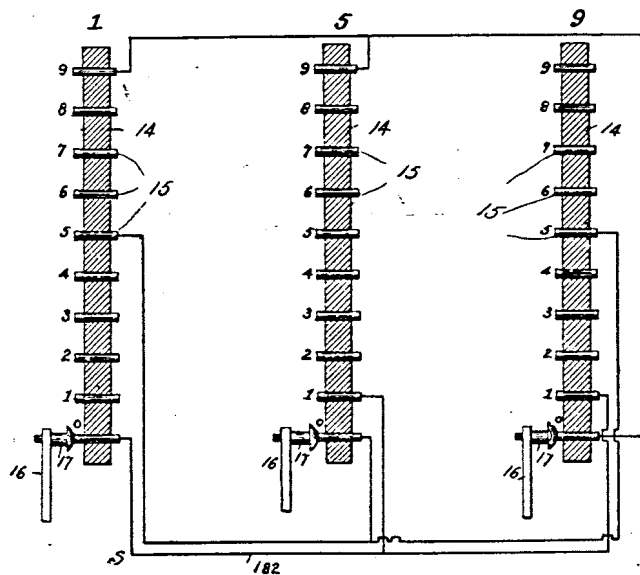


Figure 20.

To disconnect, the end piece, 162, is pushed against the shutter, 153, thereby shifting the switch, 132, from 130 to 129. The pole-changing switch, PC, is now pressed to the left a number of times, sending negative current through line 167 to the operating relay in such a way as to move the wiper up beyond the highest terminal in the row. When the wiper goes beyond the highest terminal in the row, contact 55 will be forced mechanically against 56, energizing the release magnet, 43. The release magnet

then pulls up and restores the switch to the zero position. When the release magnet pulls up, besides unlatching the step-by-step mechanism, it pulls its armature spring, 179, away from contact 175 and brings it into contact with 177. This places a dead ground on line 168, so that magnet 145 at the sub-station is energized, pulling 150 down and letting shutter 153 fall as an indication that the release of the switch at central had taken place.

It will be noted that during the time that the subscriber is giving the impulses to carry the wiper beyond

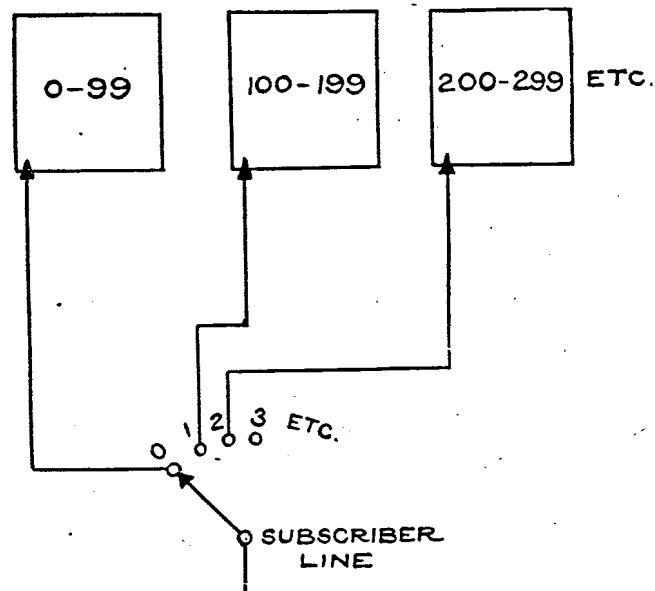


Figure 21.

the row of contacts, the working circuit through the line 167 has a shunt on it through the magnet, 145, line 168, wiper 17, and the called line and all lines in succession over which the wiper passes.

The system of numbering the line terminals in the bank was from 0 to 9 in the first row, 10 to 19 in the second row, and so on up to 99 in the tenth row. The wiper of each switch rested on 0 as its home point, to which its wire was connected and through which all incoming calls were received. If the wiper A is moved up to call another line, B, a third party, C, on attempting to call A will find A's line open. The wiring is shown in Figure 20. It shows a vertical section of the terminal banks of three switches, Nos. 1, 5 and 9. Zero is the home point for the wiper of each. The wiper, 17, carried by the arm, 16, is permanently connected to the subscriber's line. Taking No. 1 for an example, there is a wire multiplying together the No. 1 contacts of all the banks except on Switch No. 1, on which the wire runs to the zero contact. This normally connects it to the No. 1 line so that any of the other subscribers by moving their wipers can connect with it. But if subscriber No. 1 has moved his wiper over and up to call some one, any third person calling No. 1 will find the line open. But if the third person calls the called subscriber, he can get in on the connection.

The main points of this system, the first of the Ericksons, may be summarized as follows:

1. Terminals arranged in a flat, rectangular bank. This seems to be an imitation of the face of a switch-board as used in manual practice, substituting terminals for jacks.

2. One hundred lines capacity. Most inventors have started out with this as their limit.

3. Fifty per cent switching. That is, all subscribers could be talking at once.

4. Rectangularly moveable wiper, longitudinal motion for tens, transverse for units.

5. Wiper held on terminals by weight. This is rather unusual in the line of early automatics.

6. Local battery at sub-station. This was very common, and to be expected, as the idea of centralizing all battery at the exchange office had not materialized to any extent in those days.

7. Working magnets on switch controlled by a relay. This was a good point.

8. Operating relay polarized. A bad thing and to be avoided.

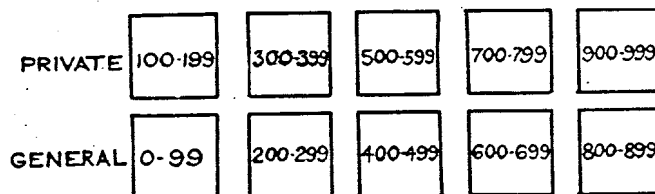


Figure 22.

9. Two levers on sub-station instrument, one for tens and one for units. This reminds us of Strowger's buttons.

10. Complete release. A good point.

11. Release signal at sub-station. This avoided the trouble which we have just recorded on the LaPorte system of the Strowger automatic. The subscriber was to keep on working the units lever till the shutter fell, which gave him the signal to quit.

12. Partial privacy.

A patent was applied for covering this system March 28, 1893, and issued December 27, 1898, as No. 616,714.

Realizing the limitations of their 100-line board, the inventors now turned their attention to larger capacity and complete privacy. They secured the increased capacity by placing side by side ten banks of 100 contacts each. See figure 21. Each bank was presided over by a wiper, and all the wipers were mechanically fastened to the same shaft but insulated from it. This shaft was capable of a longitudinal and a transverse motion, so as to bring the wipers to any point in their banks. An auxiliary switch determined which of the wipers should be used and so fixed the hundred.

This in brief was the way in which they proposed to secure the increased capacity, but there are other interesting features which make it worth while to go into the details. Complete privacy was a thing which they felt to be imperative and which they provided as described below:

In the upper part of Figure 22 is shown the arrangement of the ten banks in two rows. They were numbered as indicated. Under these ten banks were ten other banks exactly like them and placed in exact line below them. The lower part of figure 22 shows an end view from the left. For each line in the switchboard there were two contacts, one for general use, the other for private conversations. In the nearer row of banks, 0-99, 200-299, 400-499, etc., the general contacts were above and the private wire contacts below. That is, line No. 50 had its general wire contact in the proper place in the upper bank of the 0 hundred. Directly be-

low it was its private wire contact. In the other row of banks, 100-199, 300-399, etc., the general wire contacts were below and the private wire contacts above. There was a shaft, 25, which ran lengthwise between the two sets of banks, upper and lower. This shaft carried the wipers, which were springs adapted to touch the contacts. Thus 32 was a spring which could touch contacts on the back row of banks. If the shaft 25 were rotated to the left, or counter clockwise, 32 would come into contact with some terminal in the lower bank, which was the general. At the same time the other spring, 39, was brought into contact with the upper bank, which was also the general. If the shaft were rotated in the opposite way, both springs would be made to touch the private banks.

In Figure 23 is shown the ten wipers or springs mounted on the shaft 25. Each wiper is connected to one of the contacts of the auxiliary switch just below. The lever, 83, of this switch rests normally on the left contact, which should lead to the wiper which presides over the 0-hundred. The subscriber's line is connected to the lever, 83, so that its position will determine which of the ten banks the line will be connected with. The shaft, 25, can be moved by a step-by-step magnet longitudinally to select tens, and transversely to select units, the same as was done in the first Erickson system.

Figure 24 shows the general plan of wiring the machine. At the center of the diagram is the auxiliary switch which is termed the "selective switch." This is the one whose lever, 83, determines the hundred. To the left of it is another switch which looks very much like it. It may be termed the "side switch," and is moved by the "operating magnet." The lever, 139, of this side switch is connected to the base plate, 20a, of the machine, which at the bottom of the figure goes through line wire 215 to the sub-station. This wire is the talking wire of the subscriber and by means of the side switch is normally connected to a wire leading to other machines for incoming calls. The second contact of the side switch leads to the selective switch magnet, the third to the longitudinal movement magnet, the fourth to the transverse movement magnet, the fifth to the general wire magnet, the sixth to the private wire magnet, and the

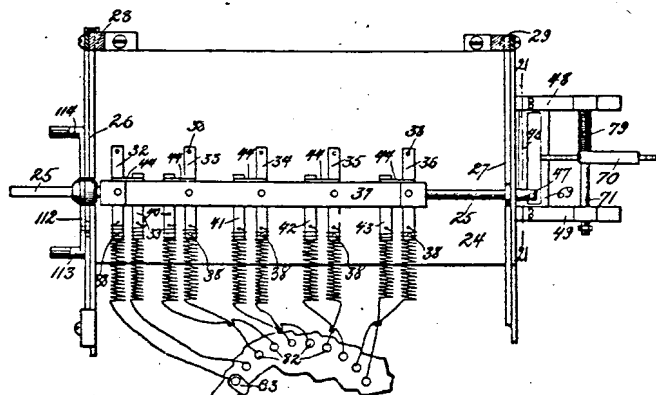


Figure 23.

last to the release. In the lower right-hand corner of the diagram is the sub-station controlling magnet which comes between grounded battery and the line wire, 214. We must now look at the sub-station, Figure 25, to see what is capable of happening there to affect the central office machine.

At the upper right hand of the figure is a sort of dial. It has six terminals, 222, 223, 224, 225, 226, and 227. These are arranged in a circle and strapped together and grounded. Three other contacts, 228, 229, and 230, are strapped together and connected to the tel-

ephone, 250, which goes to the ground. There was a crank and worm movement arranged to move two springs around the dial. Spring 234 could touch only the outer circle of contacts, and was connected to the line wire, 214, which connects at central with the sub-station controlling magnet, 161. Spring 235 on the dial can touch only the three inner contacts which are connected to the telephone and 223 and 224 of the outer circle, which project inward. It took six turns of the crank to move the springs once around the circle, going counter clockwise. The spring 235 is connected to line wire 215, which is the talking wire.

In tracing the operation of selecting a number the two figures, 24 and 25, must be constantly compared, though two of the relays of the central office machine are redrawn in Figure 25. In the normal position of the dial springs the telephone is connected to line 215 and can receive calls.

Line 214 is grounded through spring 234, so that relay 161 is constantly pulled up. To make a call, the crank is given one complete turn. This moves spring 234 off contact 222, opening line 214. Relay 161 falls back, closing two other circuits. One of these is that of the operating magnet, pulling it up and advancing the lever, 139, of the side switch to the second contact. The other is a circuit from battery 208, through the push button magnet, 157, through contact 167 and lever 162 to line 215. This ends in the push button at the sub-station, which the subscriber now pushes as many times as there are hundreds in his call. This operates magnet 157 the same number of times, which in turn steps the selective switch magnet, 92, to the proper group or bank.

The crank is now given another turn. In so doing it moves spring 234 over contact 223 and stops between 223 and 224. In wiping over 223 it grounded line 214 for an instant. This pulled relay 161 up, breaking the circuit through the operating magnet, 142. Then when spring 234 slipped off contact 223 it made relay 161 fall back again, energizing the operating magnet so that the lever, 139, is advanced to the third contact. This gives the push button control over the longitudinal movement magnet, selecting the tens. Another turn of the crank and more pushings of the button picked out the

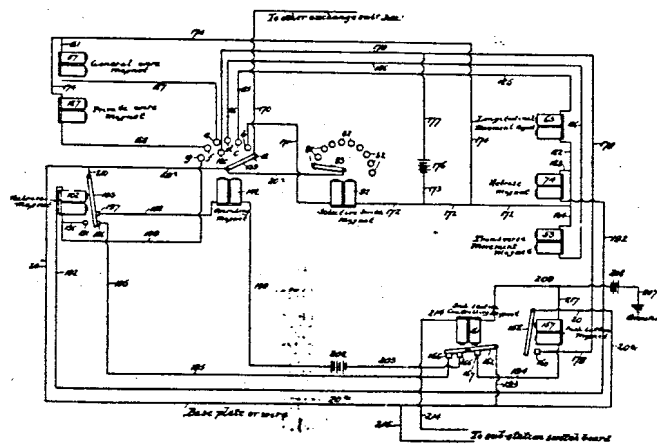


Figure 24.

units. The spring 234 is now between contacts 224 and 225. Another turn of the crank carries the spring 234 past 225 and leaves it resting on 226. In passing contact 225 it stepped the side switch to the fifth contact, where it leaves it. This energizes the general wire magnet, 117, tilting the shaft, 25 (Figure 23), so as to bring the wipers into contact with the general banks. As the selective switch, 83, has been moved to the position con-

necting with a certain wiper, the talking wire, 215, from the telephone will be connected to the desired line. The subscriber then rings the called station by a magneto and they converse. It will be noticed that during the conversation spring 235 on the dial is resting on contact 228, connecting the telephone to the line. Also spring 234 is resting on contact 226, holding relay 161 energized.

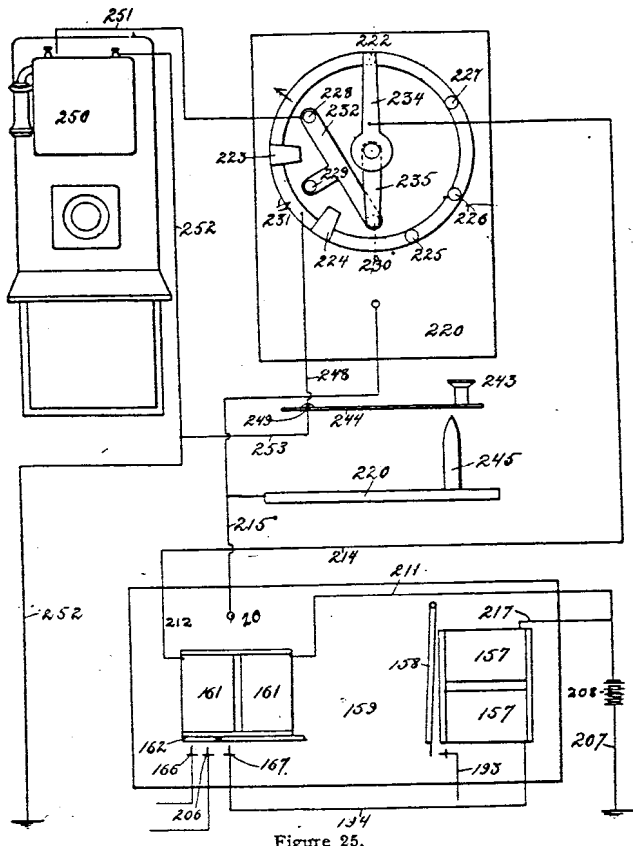


Figure 25.

If the subscribers wish to converse in private, the calling subscriber tells the called to get in on his private line, at the same time giving him his (calling subscriber's) number. The calling subscriber then gives the crank of his dial another complete turn, which moves wiper 234 from contact 226 to 227. This energizes and releases relay 161 once, stepping the side switch, 139, to the sixth point. During the movement of spring 234 from contact 226 to 227 the spring 235 made momentary contact with 223. This grounded line 215 for an instant, thereby pulling up the private wire magnet, 127, tilting the wipers in the opposite direction so as to touch the private wire banks. The particular wiper to which the calling subscriber's line is attached through the switch 83 will now rest on the private wire leading to the called subscriber.

While this has been going on, the called subscriber has been going through the operations of calling the number of the calling subscriber. On getting the connection, he moves his dial on to the 227 contact, which gets him also on the same private wire, where they may converse without possibility of being interrupted.

The release was accomplished by turning the crank of the dial one more turn, bringing spring 234 onto contact 222, where it rested normally. In slipping off contact 227, line 214 was opened, which allowed relay 161 to fall back and energize the operating magnet, 142, moving the side switch to the last point. While this is happening, spring 235 wipes slowly over contact 224, grounding line 215. This pulls up the push button magnet, 157, which in turn energizes both of the release

magnets, 74 and 102. The first current flow through the release magnets comes through lever 139, of the side switch. As the operation of the release magnet will restore 139 to its original position, it would cut off its own current. To avoid this there is arranged a contact, 191, which is touched by the lever, 103, of the release magnet. This closes the circuit independently of the side switch, and as long as the spring 235 on the sub-station dial remains on contact 224 the release magnets will be held up to perform their work. It was expected to make the width of the contact 224 such that there would be ample time for a complete release to occur.

The system of private wires is of interest in showing to what complications the inventors went to secure this end. Figure 26 shows the system. Portions of three exchange systems are shown, being those of telephone Nos. 12, 15 and 20. The lower half of each is the general bank. All the contacts numbered 12 are wired together and connected to the first contact of switch 83 of machine No. 12. The same is done with all the other lines. The private wire between No. 12 and No. 15 will be found in the upper half of the banks. It runs from contact 15 in No. 12 to contact 12 in No. 15. All the rest are arranged in the same way, as will be seen from inspection.

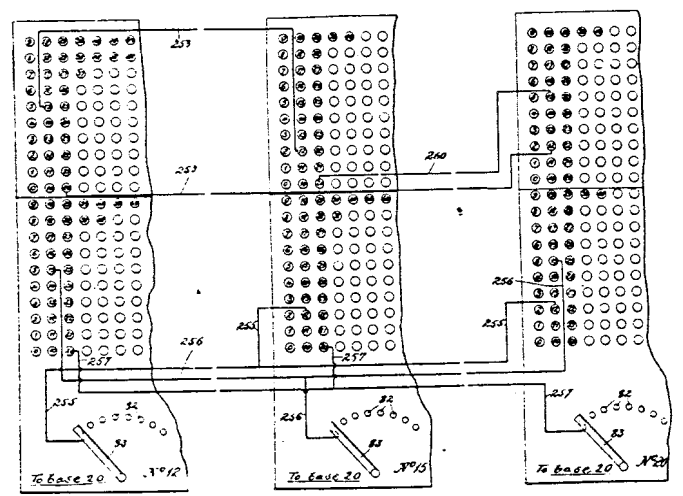


Figure 26.

The summary of the points of this system will show much that is yet embodied in the Strowger system of today.

1. One thousand line, secured by assembling ten banks of contacts of 100 each on each machine. This was rather wasteful of material and could never have made a compact system as a whole.
 2. Separate wiper for each bank. Considering the former effort of Strowger to have a single wiper travel over the whole 1,000 contacts, this was a very neat device.
 3. Relay-operated magnets. As remarked before, this was in line with substantial progress and may be counted as one of the fundamentals of modern telephone engineering.
 4. Ratchets stood free from teeth.
 5. Ratchet stop to prevent errors due to inertia.
- These two last points are mentioned because of their similarity to the Strowger devices which we have described.
6. Zero not used as home point.
 7. Wipers stood free from contacts. They were not strictly "wipers," for they did not wipe. They got rid of the difficulty of friction very neatly.

8. Battery at central. This is a very great point, it may be said to be a beginning of common battery working. It, however, did not affect talking, which was either magneto or local battery.

9. Battery normally flowing over one side of line to sub-station. Not a very good point, as wasteful of current.

10. Side switch. The operation of the device in this system which I have termed the "side switch" is so much like that of the side switch in the present Strowger machine, especially the connector, that it deserves to be noticed in particular.

11. Vertical and rotary relay action. Though there was no vertical or rotary action, yet the relations between the push button magnet, 157, Figure 24, and the sub-station controlling magnet, 161, are strikingly like the relations between the vertical and rotary relays of the modern machine. The push button magnet, 157, corresponds exactly to the vertical relay in that it is the step-by-step relay. By it the subscriber advances the wipers a notch at a time to the desired point. The sub-station controlling magnet, 161, is very like the rotary relay, for it directs the activities of the push button magnet. The operating magnet, 142, is like the private magnet of the modern switch, for it is under the control of the "rotary relay" and moves the side switch to certain points, directing what magnets shall be stepped up by the push button magnet. Thus we have typified here the vertical and rotary relays, the private magnet, and the side switch.

12. Complete privacy by special wires. This method of getting the result was rather crude and complicated, but better than nothing.

13. Fifty per cent switching.

10. The piano wire switch

Frank Lundquist and John and Charles Erickson decided that it would be advisable to move their shop to Chicago and continue their operations there. Accordingly, in the middle of March, 1893, the move was made. All the automatic machines and parts of machines were packed up and taken along, together with the unfinished pianola. The latter the Erickson brothers hoped to be able to finish in leisure hours. But the leisure hours never came, and the electric piano-player was forgotten in the greater work.

A storeroom on the South Side was rented and fitted up as an experimental shop. Here they again took up the development of their apparatus. March 28, 1893, they applied for a patent on their first system, which they had invented previously in Kansas.

All the operations up to this time had been carried on by means of the money which was furnished by John and Gus Anderson, of Lindsborg, Kan. This money was now exhausted and no more was to be had. For a time it looked as if the inventors would starve or be forced to drop the work for something which would pay. Finally terms were arranged with Masten & Son, of the South Side, under which they were to put up the money for developing the invention. The Erickson brothers were to make four switches and make them operate. The terms of the contract are described as being of the "freeze out" variety, being almost entirely in favor of the lenders. Though disliking the terms, the inventors signed up, as there was nothing else to do.

After a time the four switches were completed and set up in operation in the Omaha Building; but for some reason Masten & Son refused to furnish the money which had been promised. Again the Ericksons had to seek financial aid, and the Western Electric Company was offered the invention. They sent a man to look at it, but no further action was taken by them. Things began to look very discouraging, but in the midst of all this financial embarrassment the Erickson brothers never lost faith in the automatic system. Not that they believed that they had already perfected it, but they had confidence that it could

be made to work. During this time Frank Lundquist had not been idle, and his activity now resulted in getting the Strowger people to look at the exhibit which the Ericksons had working in the Omaha Building. After inspecting their work and plans all three men were taken into the employ of the Strowger Automatic Telephone Exchange in January, 1894. During this

year (1894) Walter S. Strowger severed his connection with the Strowger company. He went into farming and the real estate business in Kansas. After entering the employ of the Strowger company the Erickson brothers started to get out a new system, which should be a marked improvement on their previous efforts. The disadvantage of the old form of terminal bank, namely, the complexity of wiring to multiple all the lines to all the selector switches, had been apparent. In casting about for some way to simplify this they struck the idea of stretching a series of wires over a frame somewhat like the arrangement of wires in a piano or a zither. These wires would all be within reach of a set of wipers arranged at right angles to the wires, the latter being made long enough to accommodate as many wiper shafts as desired. This gave rise to the famous "piano wire" board which was first installed at LaPorte, Ind., in the fall of 1894. The best description of this board which is available is found in the patent which was later issued covering its fundamental principles. This patent was applied for Nov. 7, 1894, and was issued with the number 540,168.

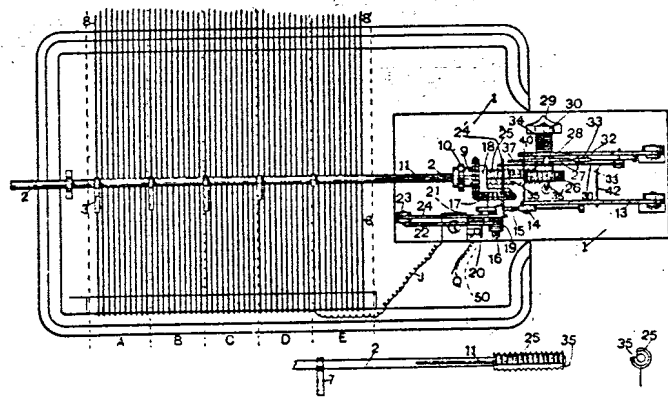


Fig. 26.

The plan of the switchboard is shown in Fig. 26. At the left are parallel lines representing the wires forming the terminal bank. They are prolonged as far as necessary for the number of machines. A, B, C, D and E are the groups into which the wires are divided, there being 10 wires in each group. The main shaft, 2, carries the wipers, each electrically and mechanically connected to the shaft. But instead of being in line, the wipers are staggered in regular spiral order around the shaft. One step in the rotation of the shaft brings the left-hand wiper into touch with the first wire of the group A. A second step in the rotation of the shaft brings the next wiper into contact with the first wire of the B group; at the same time the left-hand wiper is moved beyond and out of contact with its wire. In this way, by successive steps, the shaft may be electrically connected with the first wire in each group. The shaft 2 has also a longitudinal motion, by means of which all the wipers may be brought into line with the second, third, etc., wire of their respective groups, after which by rotation any particular wire may be connected to the shaft. Fig. 27 shows more clearly the arrangement of wipers on the shaft.

The longitudinal motion is produced by means of the usual ratchet motion, worked by an electromagnet. In the figures, 31 is the longitudinal magnet, which operates lever 32 and pawl 33. This pawl acts on the wheel 26, which is also geared into a circular rack on shaft 2. The rotary motion comes from magnet 12, acting through lever 13 and pawl 14 on a bevel gear arrangement, 17 and 18. In the normal position, Fig. 27, the detents 38 and 24, which prevent the backward motion of the longitudinal and rotary, are disengaged. To operate the switch it is therefore necessary to give a preliminary motion with the rotary magnet. This unlocks the wire 41 from its caught

position behind a projection on lever 13, letting the detents fall by gravity into position on their wheels. Then as many impulses as are desired are sent through the longitudinal magnet, thereby moving the shaft and wipers so that the latter contact opposite a certain wire of each group. They are then rotated by the rotary magnet till the proper group has been reached. This mode of selection led to the rather novel numbering which will be clear from inspection of Fig. 28. This figure shows three groups of wires and three switches. We would

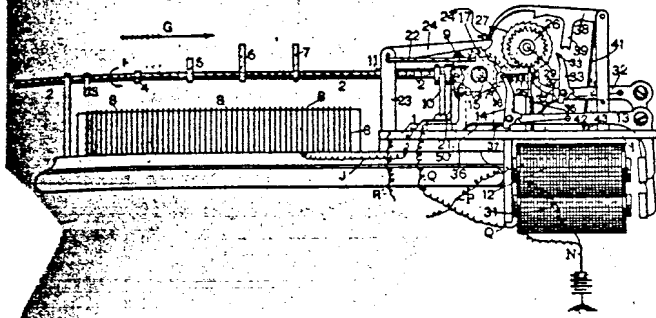


Fig. 27.

expect, from our knowledge of the decimal system of numbers, to find the units grouped in groups of tens, so that one group would contain numbers from 01 to 09, the next 11 to 19, the next 21 to 29, etc. But here the arrangement is the reverse. All the "one's" are in the first group, all the "two's" in the second, and so on. Thus the first group has from 01, 11, —, to 91, the next group has 02, 12, — to 92, etc. The necessity for the preliminary rotary movement to bring the detents into action causes the placing of figure "1" in hundreds place, though there are not as many as 100 lines on the switchboard.

The release, as far as the switch was concerned, was obtained by a mechanical interaction of the longitudinal and rotary magnets. Reference to Fig. 27 will give some idea of this action. When magnet 12, rotary, is energized it lifts wire 37, which tilts pawl 13 back so as to be in line with the notch in the lower end of 39. If, while this magnet is held energized, current be sent through magnet 31, pawl 33 will be forced upward into the notch, lifting both detents from their ratchet wheels. The rotary magnet, 12, is now released, and the restoring springs can pull the shaft around and back to its normal position. Last of all, the longitudinal magnet, 31, is released, but the detents cannot fall down again, as the wire, 41, has caught behind the projection on lever 13 of the rotary magnet. In the lower part of Fig. 26 is shown in detail the portion of the shaft having to do with the longitudinal motion. It will be seen that there are a number of teeth cut into the shaft, extending clear around it; further, that there is a longitudinal groove cut through these teeth. There is a safety stop, which normally rests in this groove. This safety stop is fixed in position on the base of the switch. There is width enough in the groove to allow the shaft to rotate one notch without getting the safety stop into one of the circular teeth. When the longitudinal motion is being made the shaft slides along with the safety stop in the groove. When the next rotary move is made the safety stop enters the space between two of the teeth and prevents the shaft from moving longitudinally. When the release is being made this safety stop prevents any longitudinal motion until the shaft has rotated back as far as it will go and no wipers are in contact with any wires. It was and is a very effective and simple means for preventing damage to the wipers by accidental longitudinal motion occurring when the wipers are in contact.

The electrical features are shown in Fig. 28. The three switches are shown in three different positions, the bottom one being in the normal position. The longitudinal magnet is represented at 31 and the rotary at 12. Both are tied to common battery in the central office. The talking wire, *R*, from the substation is connected to the frame of the switch and thus to the shaft 2 and its wipers. The home wire, or "normal," *J*, is connected to a spring 21 close to the bevel wheel 15 that moves

the rotary. On this wheel is a pin 20 in electrical contact with the frame. In the normal position of the switch this pin rests against the normal spring 21, so that incoming calls may be received through it to line *R*. The rotary magnet is permanently connected through line *P* to the substation instrument and keyboard. On the later there are four buttons, lettered to indicate hundreds, tens, units and release. Pressing the hundreds button once gives one impulse to the rotary magnet, which we have seen is necessary to bring the detents into action on the ratchet wheels. Also, in making this motion of wheel 15, Fig. 28, the pin 20 is disconnected from the normal wire *J* and connected to the longitudinal magnet 31. Pressing the tens button now grounds the *R* line, and through the rudimentary side switch just described energizes the longitudinal magnet. Pressing the units button grounds the *P* line, which operates the rotary magnet to rotate the shaft and wipers to contact with the desired wire. This same rotation also causes pin 20 to break away from spring 50, cutting the longitudinal magnet out of circuit.

It was evidently intended to work this system with only two line wires, but it requires only casual inspection of the opera-

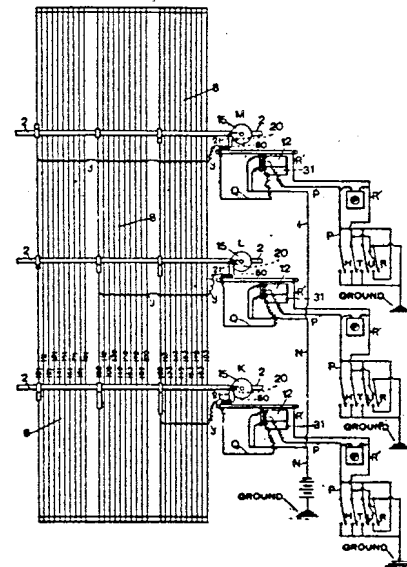


Fig. 28.

tions and circuits just described to show that, as arranged, release will be impossible. This is because of two facts: *a*. The release depends on the mutual action of the longitudinal and rotary magnets, and at the same time. *b*. The last act of selecting disconnects the longitudinal magnet so that it cannot co-operate with the other in making the disconnect.

The features of the system may be summarized as follows:

1. Connector bank one continuous arrangement of parallel wires. Wires grouped in groups of 10 wires each.
2. Shaft with plurality of wipers, staggered.
3. Longitudinal and rotary motions.
4. Both magnets acting on the shaft through gear wheel. Let this be compared with present practice, in which the action is direct.
5. Spring return for both motions. Gravity could not be used for one of them, as the shaft was horizontal.
6. Longitudinal groove, with safety stop. This was the beginning of the same device which is still found on the switch of to-day.
7. Initial motion of rotary to bring detents into action. In the modern machine this is done more simply by the first rotation of the vertical magnet.
8. Release by mutual action of rotary and longitudinal magnets. This point is worthy of note, since in modern systems the release is accomplished by very similar action, not by magnets, but of line wires and line relays.
9. Common battery selecting. A good point.
10. Side switch of two contacts. It was a very limited

imperfect switch, which later was expanded to a very great and vital usefulness.

11. Limit, 90 lines, from 101 to 199, omitting 110, 120, etc.

12. Two-line wires. This was the plan, but in putting the system into operation it required more.

13. Button keyboard at substation. This continued the practice which obtained up to that time. The main attention of the developers was absorbed in making a switch which would do all that could be asked, and it is not surprising that the substation devices should not be developed as fast as the switches.

14. Partial privacy. If some one called on the calling line of a connection he could not interfere, but if he tried to get the called line he would be connected with it.

15. Busy test. When ringing with the magneto hand generator of the substation set, if the line were the calling line of another connection, it would ring open.

16. Release electrically impossible, as at that time the longitudinal magnet was not in circuit.

The switchboard above described was built in the fall of 1894 to replace the old flat disk board at LaPorte, Ind., which had been doing service since Nov. 3, 1892. Samson battery, a form of primary cell, was used at central to operate the switches. The lines were mostly, if not entirely, open wire lines, and great trouble was experienced from grounds. The trouble was not felt in its effect on the magnets, for it took so much current to operate them that a small thing like a tree ground would not affect it; but it was very bad on the battery, running it down rapidly, so that the item of battery renewals was very large. Later the expense of this became so heavy as to be prohibitive.

The contacts obtained between the wipers and the wires of the "piano" arrangement were very good, and no trouble was

felt from that source. Being a common return system, there was a very great deal of cross talk. There were three wires and a common return, which made quite a wire plant for the days when a single wire with ground return was thought by most magneto telephone men to be good enough. The practical operation of the buttons at the substation also caused some trouble, as it seemed hard for some people to learn to use them properly.

In spite of these troubles there were evidences that the public liked the automatic switchboard. Letters were written by users of the system, after the improved board had been put in at LaPorte, which expressed satisfaction with its working.

11. Revised piano wire switch

The new switchboard at LaPorte before long began to reach the limit of its capacity, which was about 100 lines. The engineers of the Strowger company realized that this board was only a step, for they had at once started to design a 1000-line board of the "piano wire" type. They thought that by extending the shaft which carried the wipers they could cover 10 groups of 100 wires each. They proposed to make the shaft in sections, one for each hundred, insulated from each other. All

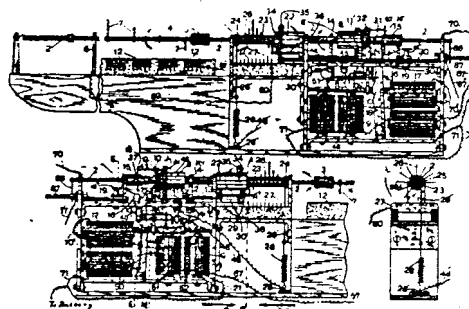


Fig. 29.

of the sections would make contact at the same time with a wire in their own groups, while an auxiliary switch determined which of the sections of the shaft should be connected to the line. In this way it was theoretically possible to select any one of 1000 subscribers. Though the board which was designed along these lines was never constructed, a patent was taken out on it, and it possesses a place in the development which is important.

Fig. 29 shows two side elevations of the working parts of the switch, with the piano wire bank indicated by a portion of one hundred. The sectional shaft, 4, is horizontal, as in the former switch. The longitudinal magnet, 17, acts directly on the shaft 2, as also does the rotary magnet 9. The form of the ratchets looks very much like those now in use. Fig. 30 shows the plan of a portion of the board, with three individual switches, the center one being complete, the outer ones partly dismantled to show details. The longitudinal detent 19 is normally in the longitudinal groove of ratchet cylinder 15. On the first rotary motion it enters the space between two of the

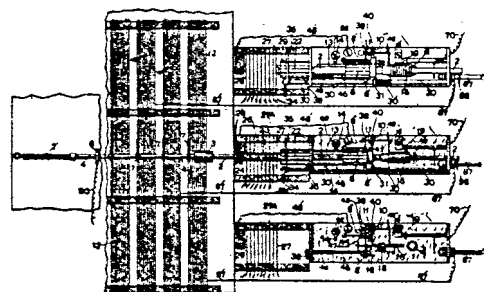


Fig. 30.

ratchet teeth. When the shaft is moved longitudinally detent 19 clicks from tooth to tooth.

The auxiliary switch which selects the hundreds is just at the right of the bank wires. Of the wires 27, there is one for every hundred bank wires. At 25, Fig. 29, is a series of wipers on a loose sleeve, which is mounted on shaft 2, but insulated from it. The wipers are staggered around the sleeve in the same manner as are the wipers in each group of the main bank. Each of the metal strips 27 is wired to one section of shaft 40.

By successive turns of one notch each the metal sleeve 23, with its wipers 26, can be connected to any one of the sections of the main shaft 40. The rotary magnet 9 is so arranged as to be able to operate either the auxiliary switch or to rotate the shaft 2. In its normal position it will act on the auxiliary switch, but after the shaft 2 has been moved even one notch longitudinally the mechanical connection with the auxiliary switch is cut out, and that with the shaft 2 cut in. The exact details of this mechanical switch-over are too complicated to warrant giving space to a complete description here. There are other details also which can be studied out by careful reading of the patent and attention to the drawings by any one who wishes to take the time, but in this discussion it is the purpose merely to state what happens and how it happens only far enough for the reader to get a good idea of the essential points.

The "normal" or incoming call line is attached to the post 87, Fig. 30, while the talking wire from the substation is permanently attached to the shaft 2, through its bearings and the frame. The pin 88, attached electrically and mechanically to shaft 2, normally bears against post 87 so as to have the talking wire connected for receiving calls. But when the switch is in use the normal line is cut off from this "off-normal switch."

The longitudinal magnet is normally disconnected from the line. Near the shaft 2 is the spring 14, which is connected to the longitudinal magnet. The pin 13, on the shaft, will touch

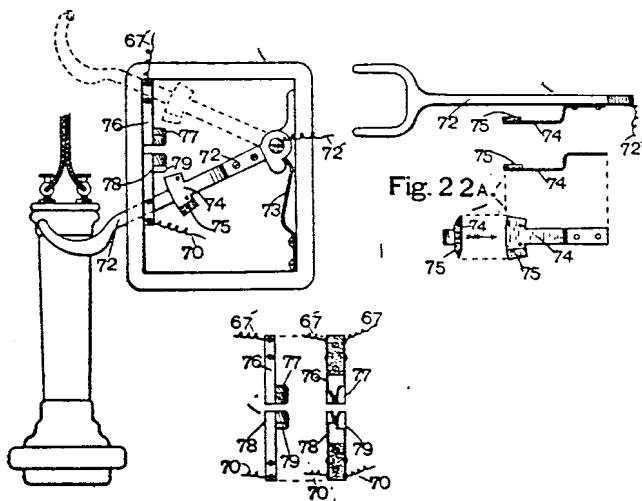


Fig. 31.

the spring 14 when the shaft is turned one notch only, and will break contact if the shaft be turned further. An initial motion of the rotary magnet is required with this switch, as with the first piano wire board, but instead of its bringing the detents into play it rotates the auxiliary switch and shaft 2 one notch each. Subsequent motions of the rotary magnet rotate the auxiliary switch only. It has part of the functions of a side switch. For the details of the main side switch one must refer to the theoretical drawing of Fig. 32. Forty-nine is a spring which is held firmly by post 50, which is attached to the frame and consequently to the talking line 70. The back contact 48 is connected to the sleeve 23, and so to all the wipers 26. The front contact is wired to the spring 14 and longitudinal magnet 17. The spring 49 can be acted on by both magnets independently. The rotary magnet 9 is permanently wired to the return line 67.

In Fig. 31 is shown the hook switch at the substation. In general, its action is as follows:

When the hook is pulled down it first opens the return line 67 grounds the end toward central. Then it does the same for the other or talking line 70, then takes the ground off line 67 and closes it up again, lastly takes the ground off line 70 and closes it up also. These openings and groundings are done by means of the spring 74, attached to the main lever, and insulated backing which it has at 75. When the lever is allowed to go up it does not affect either line.

Fig. 33 gives the general plan of the three switches and two lines connected. At the lower left-hand corner are the button

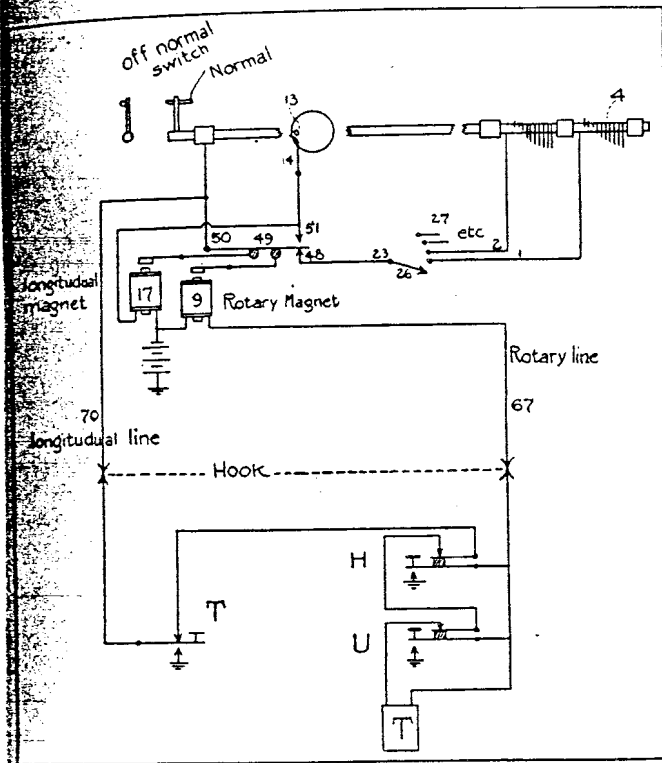


Fig. 32.

keys which the subscriber was to operate. *H* is the hundreds button, *T* tens, and *U* units. Although the wiring of these buttons is shown by this figure, reference to Fig. 32 will make their relations more clear. It will be seen that the *H* and the *U* buttons are capable of grounding the return line 67, while the *T* button similarly grounds the talking line 70. The telephone is connected normally across the two lines as if a metallic circuit were employed. But whenever any of the buttons is operated it opens the telephone circuit.

The complete operation may be explained by reference to Fig. 32. Let us suppose that it is desired to call No. 234. Button *H* is pressed twice. The first grounding of line 67, which may be called the rotary line, rotates shaft 2, bringing pin 13 into contact with spring 14, and also rotates the auxiliary switch one point. The second grounding of the rotary line 67 rotates the auxiliary switch another notch, connecting its wiper to the second section of shaft 4, which presides over the second hundred. The shaft 2 was not moved this time. The *T* button is then pressed three times, grounding the line 70 that many times. One might call 70 the longitudinal line. Through the contact of spring 14 with pin 13 this energizes the longitudinal magnet three times, moving the whole shaft up three notches. When the *U* button is pressed four times it causes the rotary magnet to rotate the shaft four notches, bringing the proper wiper into contact with the wire of the called line in the desired hundred.

The calling station can now ring the other line with the magneto generator, and by means of the series bell tell whether the called line is open or closed. If open, the chances are that it is busy. It will be noticed that the only path for the return current is through the rotary magnet to the negative battery terminal which is common to all lines. Thus the subscribers'

lines would be metallic to central, but all tied together at the office.

To release, the receiver is simply hung on the hook. As the lever goes down it first grounds the rotary line, pulling up the rotary magnet. This pushes spring 49 against its front contact 51, which connects the longitudinal magnet to the line 70. Then the switch at the substation grounds the longitudinal line 70 also, pulling up the longitudinal magnet. Now there is a mechanical relation between these two magnets such that if they are pulled up in the order just named the detents which hold the rotary motions of shaft 2 and the auxiliary switch are released. The auxiliary switch snaps back at once; the shaft follows as soon as the hook has allowed the rotary magnet to fall back. Shaft 2 rotates back, with safety stop 19, in a space until it strikes the longitudinal groove, when the shaft slides longitudinally to its normal position. Lastly, the longitudinal magnet is released allowing the side switch 49 to come against its back contact 48 and the detents to fall again into position.

There are many points of interest in this board as projected, and of them will be selected those which seem of greatest interest at this point in the history. They are as follows:

1. 1000-line capacity, or from 101 to 999. Piano wire bank grouped and subgrouped decimally. It is doubtful if this system could have been made to work commercially. If the 100-line board, the second LaPorte board, took so much current to work it, this 1000-line board, with its longer shaft and more contacts, would probably have required more current than the battery would supply.

2. Direct action of both magnets on the shaft. The cutting out of the gear wheels was a good thing.

3. Initial rotation to connect up longitudinal magnet. This has been noted in the first piano wire board.

4. Sectional shaft, each section the same as the shaft of the first piano wire board and devoted to a hundred group.

5. Auxiliary switch to connect line to any desired one of the shaft sections, hence to a hundred. This idea we have seen before in the second Erickson board which the brothers designed in Kansas.

6. Mechanical switching of rotary magnet from auxiliary switch to wiper shaft. This was a very ingenious device for doing away with one of the line wires and making the one magnet do double duty.

7. Magnets directly in the line. This was a bad idea and one which was productive of much trouble, as we have seen at LaPorte.

8. Joint action of magnets mechanically in securing release.

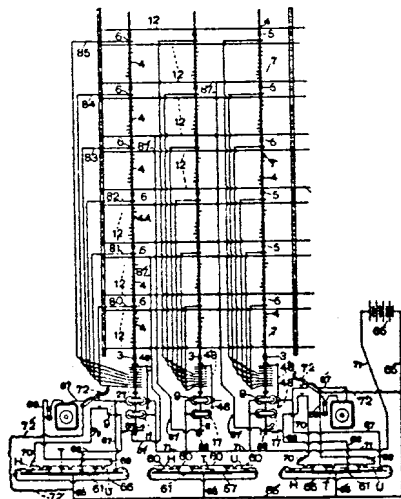


Fig. 33.

This has developed in our day into an electrical co-operation which is far better.

9. Special release switch to connect longitudinal magnet when releasing. This magnet was normally out of circuit, and on the former board we have seen that this fact prevented release. This simple addition of a switch has made release possible.

10. Talking and ringing through the rotary magnet to common return in office. It is very likely that the ringing current would have caused some trouble if the board had been put into actual practice, since the pulling up of the rotary magnet by the ringing current would tend to disconnect the line 70 from the auxiliary switch through which the ringing was taking place. How much chattering this might cause could only be determined by trial.

11. Buttons at substation open talking circuit while sending impulses. Compare this with the action of the dial in the present automatic telephone, either local or common battery.

Though the piano-wire form of switchboard simplified the multiple wiring of the banks, it still did not give sufficient capacity. The reason is that each wire of the bank occupied the entire row, limiting the growth of the number of lines to the addition of more wires below. If this is compared with the original switch of A. B. Strowger it will be seen that it con-

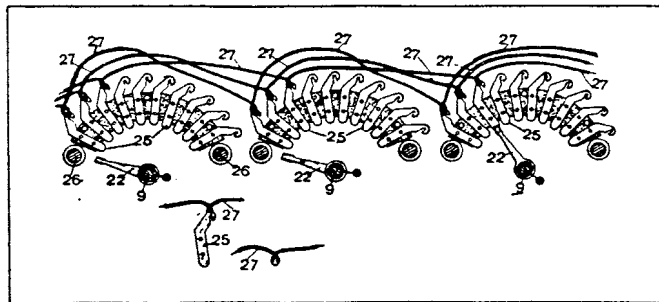


Fig. 34.

tained many contacts in each row, so that a large number of lines could be reached by rotating the wiper in any one level. In the effort to increase the capacity, the engineers of the Strowger Automatic Telephone Exchange now returned in part to this original principle.

Patent No. 638,249 was applied for Dec. 16, 1895, and covers the improved board, which they produced at that time. It was the first to have the present form of bank, which is illustrated in Fig. 34. The banks were built up of rows of contacts. Each row consisted of 10 brass punchings, each punching having two holes which fitted over raised places in the separators which were used to keep the layers apart. These separators were made of electrose, a composition which was being introduced into the electrical field to take the place of hard rubber. The whole bank, consisting of 10 rows, was then clamped in a frame. The outer end of each punching was provided with a hook to receive the multiple wiring, the details of which are clearly shown. To reduce the labor of wiring it was proposed merely to sever the insulation at equal distances on a continuous wire, slip the covering back a little, and make a half turn of the bare wire on the hook. After soldering, the insulation would slip back and tend to cover the joint.

The wiper used was very much like that of the piano wire board, being only slightly modified to fit the new brass punchings. The idea of several banks on each machine was retained, there being a plurality of wipers on the shaft and an auxiliary switch to give the subscriber his choice of banks. The whole machine was raised to the vertical position, so that it became proper to speak of a "vertical" and a "rotary" motion, just as is done now. Thus, if the shaft made three movements vertically and four in a rotary manner, all the wipers would rest on number 34 of their own hundred. If there were three banks, this would enable the subscriber, by attaching his line to the proper wiper, to connect with No. 134, No. 234 or No. 334.

The ratchet cylinders for the vertical and rotary were changed in several respects, though only by adding extra duties. Referring to Fig. 35, 15 is the rotary ratchet cylinder, mounted loosely on the shaft, with pin 15' projecting downward. The auxiliary switch, 18, is mounted rigidly on the shaft, 9, while a spring, 15', runs from an attachment on the shaft at 17 to the pin 15'. The ratchet cylinder 15 also carries a radial arm,

20, which has a hole in the end of it. The body of the switch, 18, is made of insulating material and holds a curved row of metal pins, 21, each of which is wired to one of the wipers below (22, 22', 22'').

This arrangement allows the following action: When the rotary magnet acts the first time it does not affect the shaft, merely turning the ratchet cylinder with the attached arm, 20. At the end of any number of impulses the hole in the end of the arm is directly over one of the pins in the auxiliary switch. If now the vertical movement begins, that pin will be lifted into the hole in the arm, establishing an electrical connection between the shaft, 9, and one of the wipers, the latter being normally insulated. The auxiliary switch also couples the rotary ratchet cylinder to the shaft so that rotary impulses will now cause the shaft and wipers to rotate to the desired point.

There was a complicated mechanical interaction between the vertical and rotary magnets to secure the release. In its essentials it was like that used on the piano wire board and, while interesting as a mechanical device, there is not space here to try to make it clear. The vertical and rotary detents, which prevent backward motion during selection, were combined on one piece, very much like the present practice. They were normally held out of the way by the rotary magnet, but upon the first movement of the latter the detents were dropped into place. In releasing, the rotary magnet was first energized, placing a pin in the way of a tailpiece on the vertical pawl. Holding the rotary energized, the vertical magnet was pulled up, the tailpiece riding upward and lifting the detents from their cylinders. Then the rotary magnet was released, bringing its pin over a lever from the detents, holding them out of the way. Finally the vertical magnet was released.

To give a better idea of the general features, reference is made to Fig. 36, which is a theoretical diagram of one machine and its substation. At the latter is any magneto telephone, *Tel.*, with the same keys as were used on the piano wire board. The hook switch is arranged to close and open the lines on the downward motion so as to operate the release. The vertical line is connected to the frame at two places, through spring 45, armature 42', and also through the off normal switch, 32. The normal line also taps off the vertical line and runs to the banks to receive incoming calls.

At 36 is a rude sort of side switch used for cutting the vertical magnet into and out of circuit. 35 is a strip of metal which is in line with spring 36 as long as the shaft, 9, has

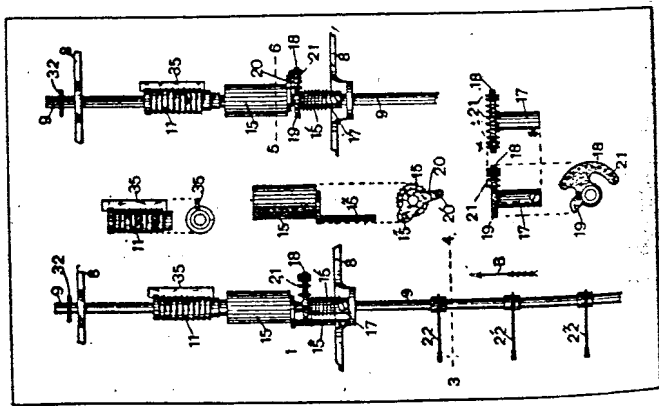


Fig. 35.

not rotated. Spring 36 is normally kept from touching 35 by the lever 40, which is worked by the detents. At 18 is the auxiliary switch, whose construction and operation have been described.

The rotary line runs directly to the rotary magnet, from which it is connected through the magnet 42 to negative battery. *D* is the main battery with its positive grounded. Its negative end is connected to a wire which forms the common return in the office. Over this common return come all the

ing and talking currents on all the lines, for they are all together here. Besides operating the rotary motion of the auxiliary switch and the wipers, the rotary magnet has important additional duties, chiefly concerning privacy. It is shown with two armatures, though it has but one. Both magnets 41 and 42 act on the same armature, 42'. The latter normally rests against the stop, 43, on the spring, 45, and makes electrical contact with it. When 42 is energized it pulls down against the insulating stop, 44. But the rotary magnet moves 45 by means of its insulated finger, 49. Thus, since the rotary magnet draws its current through magnet 42, every impulse the armature 42' is drawn down and the spring 45 is forced to the left and against the contact 55. While pulling up, the rotary magnet closes the contact 52-53 before affecting spring 45, and while falling back, contact 52-53 is the last to break.

In selecting a number the hundreds button is first pressed the desired number of times. This grounds the rotary line, operating the rotary magnet and magnet 42. The first movement of the rotary magnet releases the vertical and rotary detents so that they will prevent any backward motion. As the detents fall into place, they let spring 36 come into touch with the metal strip 35. The actions of the rotary magnet and magnet 42 on each other have no effect at this point, and the rotary magnet simply moves the auxiliary switch, 18, to the pin representing the desired hundred.

When the tens button is pressed, the vertical magnet is operated over the following path: From ground at the substation over the vertical line to the off normal switch, 32, through shaft 9, metal strip 35 to spring 36, thence to the vertical magnet and negative terminal of battery *D*. The first upward movement of the shaft caused the pin on the auxiliary switch to lock the rotary ratchet cylinder to the shaft, as before described.

On pressing the units button, the rotary line is grounded, operating the rotary magnet, which now causes the shaft and wipers to rotate. The first rotary motion of the shaft breaks the connection at the off normal switch, 32, and also at the spring 36. In stepping around to the desired number, the wiper with which the auxiliary switch has connected the line wiper over all intermediate lines. When the rotary magnet pulls up, it connects magnet 41 to the wiper by means of contact 52-53. Current can now flow from battery *E*, through magnet 41, contacts 52-53, frame, auxiliary switch, wiper, line terminal in bank, vertical line of line past which the wiper is passing, telephone instrument, rotary line, back to common wire in the office, which is also the terminal of the battery *E*. If the line

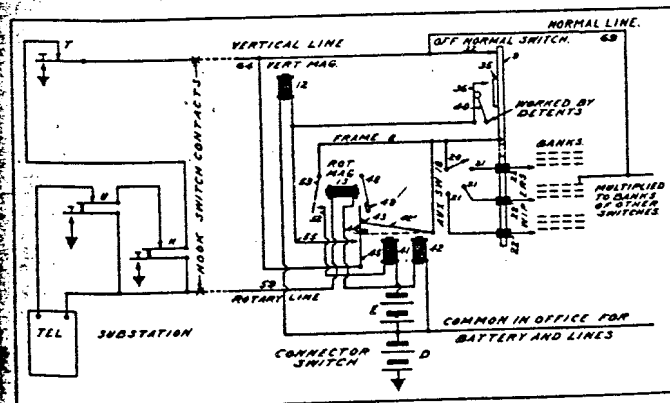


Fig. 36.

past which the wiper is moving is not in use, this current must flow through the bell at the station. This is wound to 1000 ohms resistance, so that the magnet 41 will not be able to hold the armature 42'. But if the line is in use, the lower resistance of the talking set allows the magnet 41 to hold armature 42' down till after the rotary magnet has allowed spring 45 to return to the right. In this way the armature 42' is caught under the insulating pin 44 and held there. This opens the vertical line so that the persons talking cannot be

overheard. In passing on to the next position, this open condition is removed if that line happens to be idle. If the called line is found to be disengaged, it is rung by the magneto generator of the calling station.

A simplified sketch of the line over which ringing and talking is done is shown in Fig. 37. It needs no comment. The four magnets through which voice currents pass will do the rest. Summing up the system, omitting points retained from the piano wire board, we have:

1. Present form of bank, practically as now used.
2. Details of wiring multiple. This was very well done and

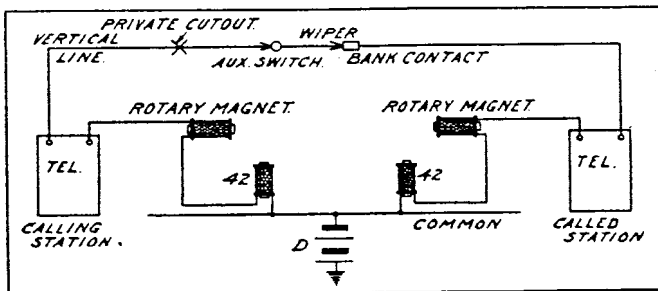


Fig. 37.

went a long way to shorten the labor and expense of this part of the switch.

3. Vertical motion against gravity. The beginning of modern construction.
4. Auxiliary switch used as coupler to switch the rotary magnet mechanically from hundreds to units. Note that in these last two systems this mechanical switching appears, and that the tendency in these days is to do the switching of functions electrically.

5. Private cut out. This seems to be the first electrical private device which secures privacy by opening the line of the person trying to cut in. Note that this is present practice.

The system just described was developed during the winter and spring of 1895. In June of that year it was installed at LaPorte, Ind., to replace the piano wire board which had been giving service. In August, 1895, a 200 line board of the same kind was installed at Michigan City, Ind., also replacing a piano wire board, which had been installed there in the preceding spring.

In November, 1895, Mr. E. A. Mellinger joined the Strowger Company as one of its experimenters. Mr. Mellinger had been attending school at Ames, Ia.

12. Plaster of paris banks

The new form of switch having electrose banks which was installed at La Porte and at Michigan City proved to be an improvement over the piano-wire form, but certain bad qualities in the insulating strips soon began to appear. It began to warp and swell, varying the distances between the contacts and throwing the rows out of line. This caused too much friction, which is the main thing which had been bothering inventors all along.

In the summer of 1895 Charles J. Erickson, of the Strowger company, designed a bank made of plaster of Paris. A steel mold was made, having its inside of the form desired for the insulating part of the bank. The mold was built up in such a way that the brass contacts could be laid into it in rows, certain recesses holding them in perfect alignment. Plaster of Paris was now poured into the mold and allowed to set. When sufficiently hard, the mold was removed and the casting dried in a moderate oven. Here the moisture was completely driven off. To prevent its re-entrance, the bank was boiled in paraffine till thoroughly filled. The contacts were then cleaned by careful buffing with walrus hide.

This produced a bank which was superior to the electrose bank and was used as late as 1902 or 1903. The first board having these plaster banks was installed at Rochester, Minn., in November, 1895. It was of 200 lines capacity and replaced a piano-wire board which had previously been in service. The switches were in other respects like those at Michigan City, which have been described.

With the growth of exchanges came increasing cost of apparatus and of giving service, and about this time party lines were beginning to be a very live question as an aid in cutting down expenses. The automatic system as yet had been able to supply only individual line service. To meet the argument on this line Mr. Strowger and Mr. Keith devised a lock-out party line system in the fall of 1895 or winter of 1895-6. The

13. Party line systems

patent was applied for on Feb. 19, 1896, and issued under the number 589,798.

As this party line system was designed to work with the type of board known as the first piano-wire board of La Porte, it will be well to recall the manipulation of its line wires in making a call. The detents were held out of contact with the ratchets and required a preliminary impulse on the rotary line to let them down. Then the vertical wire was contacted to earth, moving the shaft and wipers longitudinally. Finally the rotary was again used to turn the shaft to bring the proper wiper into touch. In releasing, the rotary line was first grounded to move a certain pin on the switch into the path of the longitudinal magnet. Holding the rotary closed, the longitudinal magnet was energized by the other wire, lifting the de-

tents off the ratchets so that the shaft could return to its normal position. Then the rotary was released, followed by the longitudinal, leaving the detents clear of the ratchets.

Referring to Fig. 38, we have a three-station line shown in diagram. A telephone receiver represents the entire magneto telephone, which was used for ringing and talking. Each intermediate station, as *B* or *C*, has two magnets with interlocking springs. Spring 11 tends to go to the right and rest against contacts 15 and 14. Magnet 10 can pull to the left and, by means of its lever 9, push spring 11 until the latter catches behind the dog of bell-crank 16. While energized, lever 9 breaks contact with spring 18. Magnet 17 when energized, releases spring 11.

The vertical side of the line 34 runs from central and loops in series through magnet 17 of each intermediate station. But, in the normal position, magnet 17 is short-circuited by the contact between lever 9 and spring 18. The rotary side of the line 35 goes through the hook contact, 7 and 8, of each station, and also through magnet 10. Thus from each station there is a clear vertical line of minimum resistance to central, but

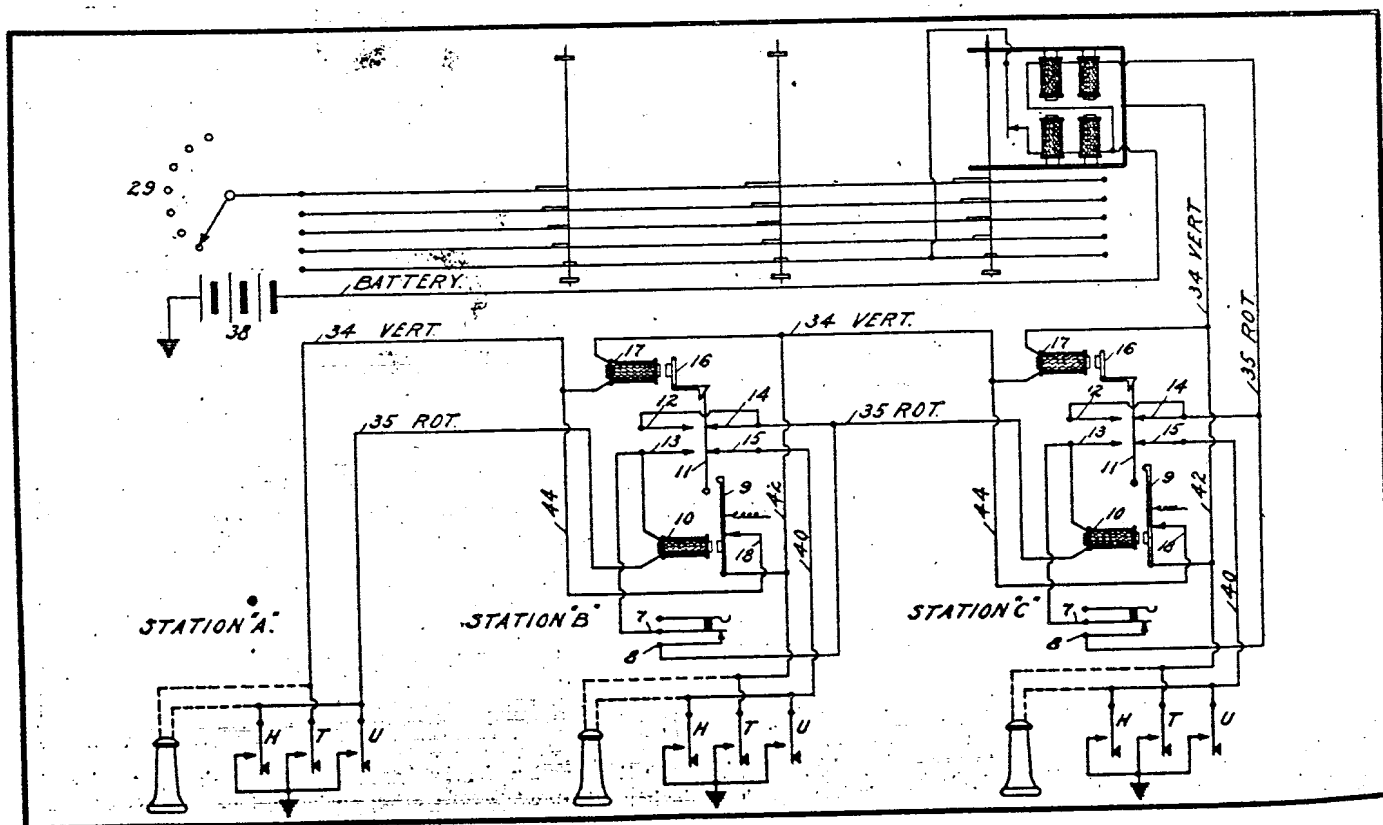


Fig. 38.—Circuit of a Three-Station Automatic Line Designed in 1895.

the rotary line must go through all the magnets 10 and hook contacts 7-8 of the intermediate stations.
 Suppose that station B desires to call some number, such as 34. He would first remove his receiver from the hook, thereby cutting off the rotary line from all the stations between him and the end of the line. He would press the H button twice.

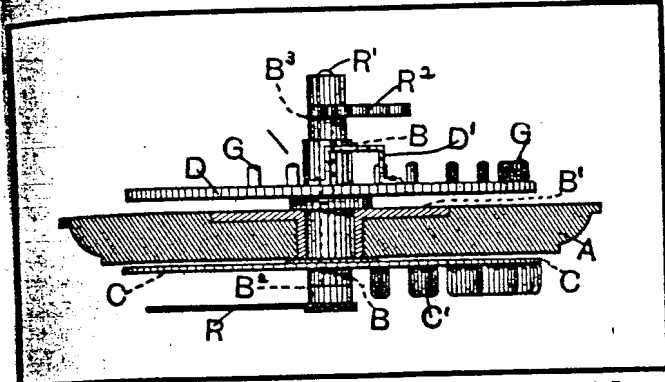


Fig. 41.—Side View of Dial Sender, Showing Arrangement of Parts.

In addition to operating the switch at central, this magnetizes magnet 10 at each station between station B and the office. When magnet 10 pulls up it cuts off the H and U buttons on the keyboard by breaking contact 15. It also short-circuits the hook contact 7-8 by the spring contact 11-12-13, which is locked by the bell crank 16. Button T would then be pressed three times, which would affect only the switch at central, since the spring contact 18 on lever 9 acts as a short-circuit on the magnet 17. The rest of the operation is as if on an individual line. Ringing was done by the subscriber with a magneto generator, and if the called party was also on a similar party line, code ringing was used to get the proper station.

To release, the same manipulation was required as for an individual line and was performed by the hook. Grounding the rotary line pulled up all the magnets 10 between the calling station and the office. This took the short-circuit off magnet 17 so that when the vertical was grounded the bell crank would be pulled up and release spring 11. Thus all the stations were restored to their normal condition.

With reference to this system we may mention:

1. The series feature, which requires both line wires to be looped into each station.
2. The terminal station, which was different from the rest on the line. It had no special apparatus.
3. The use of series magnets through which the talking current had to pass. This was a bad feature, as there were enough such magnets in the switches at central and more would only cut down transmission to a greater degree.
4. Standard operation, in that a party line station called and selected in exactly the same way as a straight line station. This was a good point and should be the standard for all systems. As far as possible all the stations on a system should be manipulated in the same manner.

This lock-out system was tried out on a party line at La Grange, Ill., in connection with the automatic system then operating at that place.

During the spring of 1896 there was considerable activity in exchange installation, the Strowger company using the

Michigan City type of switch, with the plaster of Paris bank. A few may be mentioned as follows:

- March, 1896, Albuquerque, N. Mex., 400 lines.
 - March, 1896, Trinidad, Colo. Mr. E. A. Mellinger took charge of this plant.
 - May, 1896, Amsterdam, N. Y., 200 lines.
- This spring Mr. Frank A. Lundquist left the employ of the Strowger Automatic Telephone Exchange.

14. The first dial

Up to this time the old keyboard had been used for impulse transmission at the subscriber's station. The entire attention of the group of engineers had been directed toward developing a good switch. We have seen how the necessity for an automatic release was the first improvement in the substation to force itself to the front and demand attention, resulting in the mercury "pill box" release and the latter type of springs associated with the hook. The array of buttons remained as a valid objection to the automatic, since it made the operation of calling rather complex. During the spring of 1896 the engineers were engaged in inventing a device to take its place and produced the first dial sender which approximated the present form. It must be remembered that the dial idea had been used by Connolly and McTighe certainly as early as 1883, as well as by the Strowgers in 1891. The patent for the dial which is described below was applied for Aug. 20, 1896, and bears the patent No. 597,062.

The work which this dial was required to do was as follows: Ground the rotary line as many times as desired for the hundreds; ground the vertical line similarly for the tens; and ground the rotary line again for the units. Hanging the re-

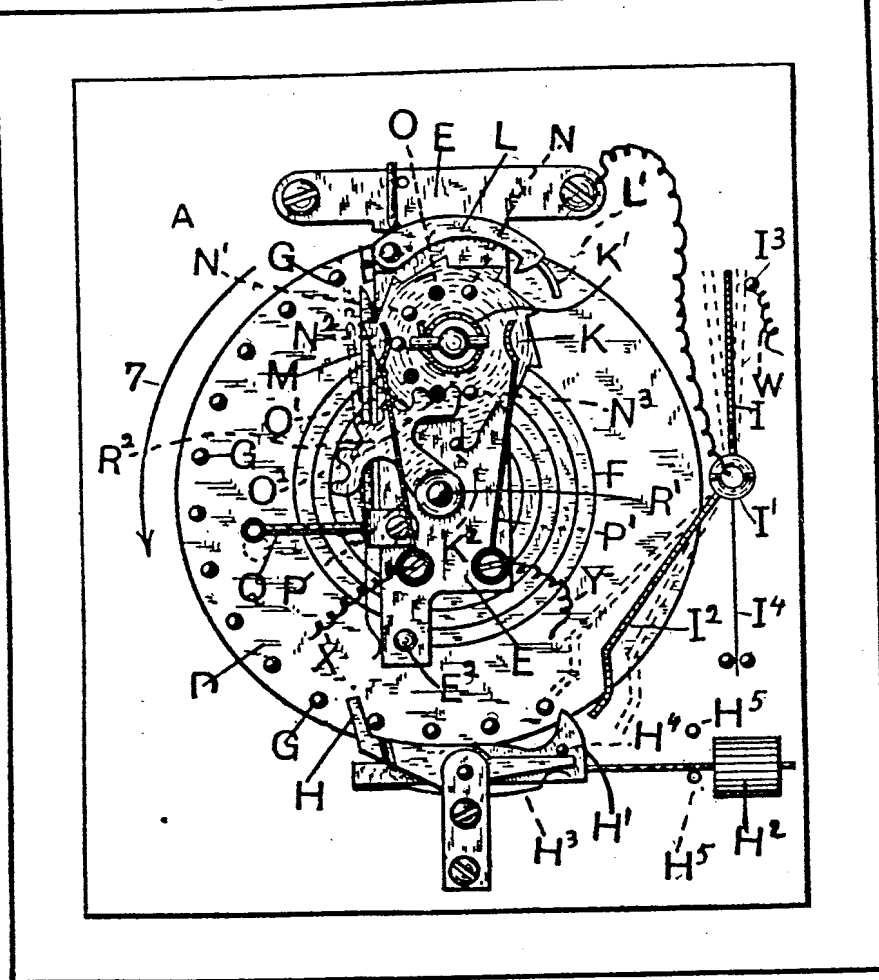


Fig. 40.—Rear View of the Dial Sender.

ceiver on the hook must reset the dial to its normal position. Fig. 39 shows the appearance of the dial as it appeared in use. Instead of holes, there were projecting vanes C'. The back is shown in Fig. 40. The dial C is mounted rigidly on a hollow

shaft *B*, Fig. 41, which shaft extends from B^2 to B^3 . Wheel *D* is mounted securely to the inner end of shaft *B* and carries a number of equally spaced metallic pins *G*, Fig. 42. Between the supporting frame and the shaft *B* is a coiled spring *F*, which

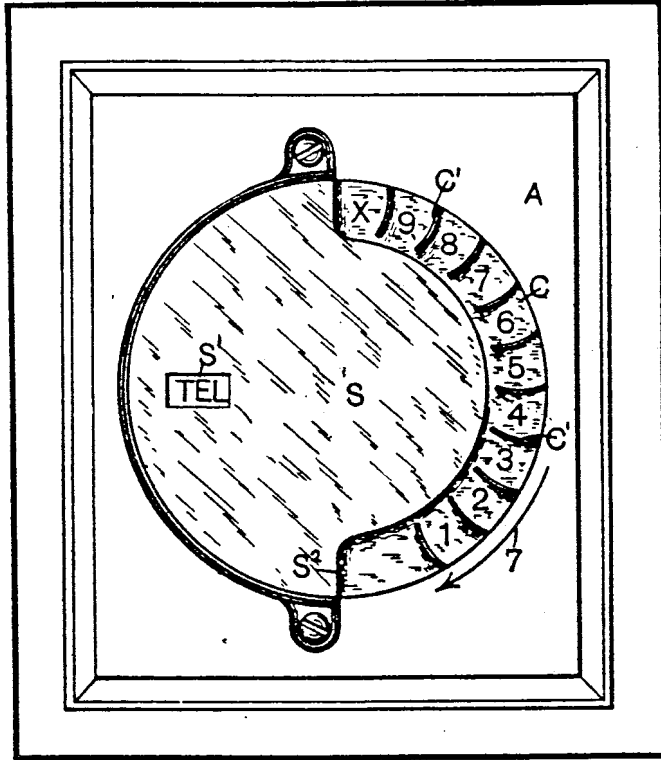


Fig. 39.—First Dial Sender of Type Now Used on Automatic Telephones. is under a slight tension and tends to rotate the shaft in the direction opposite to that indicated by the arrow, Figs. 39 and 40. The pins *G* on the wheel *D*, Fig. 40, serve two purposes,

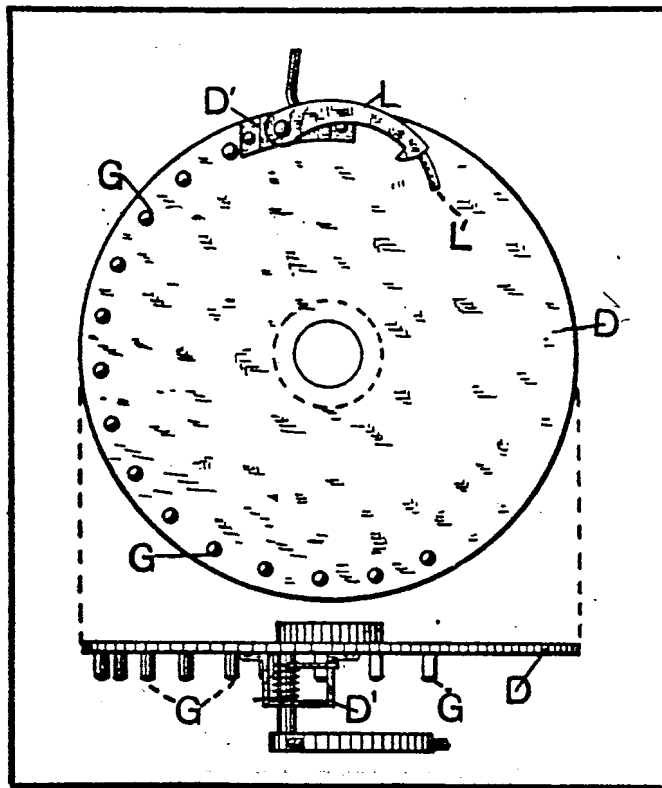


Fig. 42.—Detail of Step-by-Step Circuit Breaker.

namely, to engage the pallets *H* and *H'*, whereby the speed of the dial is limited, and also to move the spring *I*, which makes the step-by-step contact at *I* and *P'*. Wheel *D*, with its accessories, are termed the "step-by-step circuit breaker."

At *D'*, Fig. 42, a pawl, *L*, is mounted on wheel *D*. It is adapted to engage the teeth of a ratchet wheel, *K*, Fig. 40, whenever wheel *D* is moved, but is so arranged that after moving ratchet wheel *K* a little more than one notch the pawl *L* will be withdrawn so that it cannot turn it further. In the normal position of the dial *C* and the wheel *D* a small upwardly projecting wire strikes a stop and holds the pawl away from the teeth of ratchet wheel, *K*. Mounted on the latter are seven pins, which serve as cog teeth, and four of them as contact points for the springs *P* and *P'*. Pins *N*, *N'*, *N²* and *N³* are of metal and can touch the above-mentioned springs, *P* being wired to the rotary line and *P'* to the vertical line. The other pins, *O*, *O'*, *O²* are too short to touch the springs *P* and *P'*. This device is called the "circuit changer."

Though not essential to the operation of the dial, an indicating device was added in the form of a sector, *R*, Fig. 43, where it is shown in its normal position. This sector is mounted on a solid shaft, *R'*, Figs. 40, 41 and 43. This shaft runs through the hollow shaft *B* and carries on its inner end a segment of cogs, *R²*, Fig. 40. These cogs mesh into the pins on the ratchet wheel *K*.

In making a call the receiver is taken from the hook and

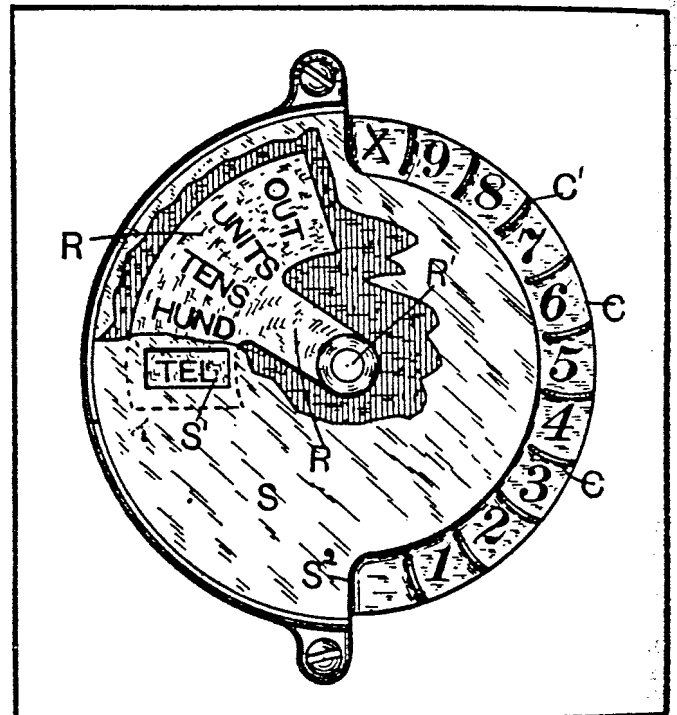


Fig. 43.—View Showing Indicating Device of Dial Sender.

the separate digits of the number pulled as in the modern automatic. On the down stroke the pins *G* on wheel *D* slip past the pallets *H* and *H'* without moving the governor. They also slip around the end of spring *I*, moving it in the downward direction so that contact *I* is not made.

Near the beginning of the down stroke the pawl *L* acted on the ratchet wheel *K*, pulling it around one notch. This caused spring *P* to come into contact with pin *N'*, and also moved the sector *R*, Fig. 43, to expose the word "Hund," instead of "Tel."

When released the dial slowly clicked back to the normal position, the coiled spring *F*, being held in check by the governor acting through the pallets *P* and *P'*. During this motion the pins *G* on wheel *D*, Fig. 40, caused spring *I* to make contact with *P'* as many times as the digit pulled. *P'* goes to ground, spring *I* is attached to the frame of the sender, as is also wheel *K* with its metal pins. This causes the grounding of the rotary line.

On pulling the next digit, wheel *K* is rotated another notch, bringing pin *O* under spring *P*, insulating it, as it is too short to touch, while spring *P'* touches pin *N²*. On the return of the dial, the vertical line is now grounded. Finally pin *N* is brought under spring *P* and the grounding of the rotary line is secured.

At each of these steps the sector *R*, Fig. 43, has been moved along so as to indicate the digit which was then being pulled. In case the subscriber pulls another time, the signal shows "Out," indicating that he is out of connection and must hang up and try again.

When hanging up to release, the lever of the hookswitch bears down on the lever *Q*, Fig. 40, which pulls the detent *M* out of contact with the ratchet wheel *K*, and lets it fly back to normal.

The first exchange to be equipped with this dial was an interior system in the city hall of Milwaukee, Wis., which was installed during June, 1896.

15. Early trunking systems

We have now arrived at a very interesting stage in the development of automatic switching, for in the summer of 1896 the engineers of the Strowger Company started work based on an entirely new principle, one which they had never before tried. This idea was to use primary and secondary switches, instead of trying to make one switch of sufficient capacity to reach every line in the exchange. Although this was a new idea to them, it had been suggested by others before. J. W. McDonough, of Chicago, Ill., applied for a patent on such a system May 21, 1891. (See patent No. 538,975.) Before him, James G. Smith, of New York City, patented a trunking scheme for telegraph lines which could have been easily adapted to telephone work. It was described in a previous chapter.

On Feb. 18, 1893, Mr. Smith applied for the patent No. 550,728, which was an adaptation of his old telegraph system to automatic telephony. He also got out another system (Patent No. 550,729) about the same time, by means of which he proposed to operate toll lines between cities. Jan. 10, 1896, Moise Freudenberg, of Paris, France, applied for a patent (No. 556,007) in this country on a system of primary and secondary selectors, being an extension of another system which he and Apostoloff had previously worked up. (Patent No. 546,725.) As these systems previous to the summer of 1896 were all

rather crude and in some respects impractical, only a brief mention will be made of each.

The nature of the system of J. W. McDonough is indicated in Fig. 44. The central switch *A* consisted of a number of rings arranged one above the other. Between the members of each pair of rings was a carriage holding a magnet and certain levers and catches. There was a vertical shaft in the center of the switch, and to the shaft were rigidly attached as many arms as there were carriages. The shaft was power-driven, and the arms pushed the carriages continually around the circle. Each of the groups of 0, 1, 2, etc., consisted of 10 wires, and all the wires in each group run from the central to another particular switch, as for instance, group 0 to *B*. From the switch *B* extend 10 groups of wires of 10 wires each, and each group runs to the last switch, *C*. From there run the subscriber lines, 10 in number.

In general construction the switches *A*, *B* and *C* are alike. Around the outer edge of the rings are vertically arranged 10 or 100 "gates." These gates could be touched by the carriages in their rotations. The gates were each attached to one of the radiating wires. While the carriages were being revolved by the arms, there was a succession of signals sent out on each line. Thus, in making a call, subscriber 0-0-6 was expected to take his receiver from the hook, listen to the signals, 0-0-1,

0-0-2, 0-0-3, etc., and press a button when he hears his own number, 0-0-6. This stops a carriage in switch *C* and connects him to a line to *B*.

As the carriages in *B* go around he will hear signals as follows: 0-1, 0-2, 0-3, etc. When his own division number, 0-0, is given, he presses his button again, stopping a carriage and giving a connection to switch *A*. The subscriber now hears

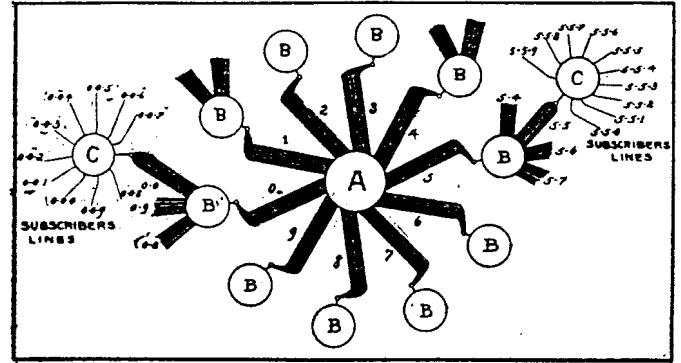


Fig. 44.—The McDonough Automatic Telephone System.

the numbers of the gates past which the carriages are passing, and on hearing the first digit (5) of the desired number (for instance, 5-5-2) he presses his button again, giving him a trunk to switch *B* of the fifth group. In a similar way he picks his way to the end of the call.

The fundamental conception was good, namely, the division of the apparatus and subscribers' lines into groups and divisions and trunking from one to the other. Switch *A* was to be the distributor for all the calls in the exchange, and any subscriber could use any trunk to any other group or division. Another point of interest is that as the carriages of *A* passed the 10 gates leading to any group, the signal of that group was repeated once for each gate. If he pressed his button for any of them, he would get that trunk. Thus the subscriber did his own selection of the non-busy trunk, a thing which is now done automatically.

Though the idea was good, the means for accomplishing this trunking were practically unworkable. Granted that the apparatus could have been made to work, it would take an expert to pick his way to the center of the system and out again to the called line. But it shows how early the necessity for a trunking system was realized.

Although J. G. Smith changed some of the details of his automatic telegraph system to suit the telephone, the main features remained the same. These main features are power drive through a long shaft, completely circular bank of contacts, a clutch-operated wiper, and an electrically-controlled dial. The

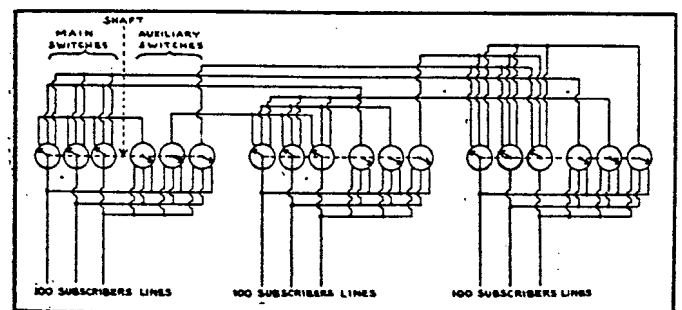


Fig. 45.—Trunking Arrangement in the Smith System.

inclusion of some peculiarly telegraphic ideas is noticeable, such as circuits normally closed with battery current flowing, also the looping of battery in series with the main line.

Mr. Smith proposed to increase the capacity of automatic exchanges in two ways: first, by lock-out party lines; second, by trunking between groups by auxiliary switches. As we are interested in trunking, the former will not be described here. His proposal as to the latter may be stated in the following

words: "suppose that each set of contacts (in the circular bank) instead of leading to a subscriber's central office instrument and through it to the subscriber's circuit, should lead to another frame with a capacity of 100 sets of contacts, and each of the latter sets of contacts lead to a subscriber's central office instrument and through it to a subscriber's circuit, it will at once be seen that the capacity of the system is increased just 100 times. Thus, with small frames which will accommodate 100 sets of contacts only, not less than 10,000 subscribers might be accommodated at one central office."

Fig. 45 shows the scheme of arrangement of the proposed trunking. Only three subscribers' lines and main switches are shown in each group, where there are supposed to be 100. Also the three groups are taken to represent 100 groups. If there are 100 groups of 100 lines each it will call for 100 auxiliary switches and 100 main switches in each group, making a total of 20,000 switches in a 10,000-line board. Moreover, there is only one trunk from each group to each other group, so that only one person at a time can talk from one to some certain other group. We would call this 1 per cent trunking. He could have obtained 10 per cent trunking in a 1000-line board by utilizing his automatic selection of a non-busy line as given in his previous telegraph system (Patent No. 481,247, applied Nov. 2, 1889), which principle he applied about this time to toll line selection between cities.

Instead of entirely giving up the contacts of the main switches to lines running to auxiliary switches, Mr. Smith proposed

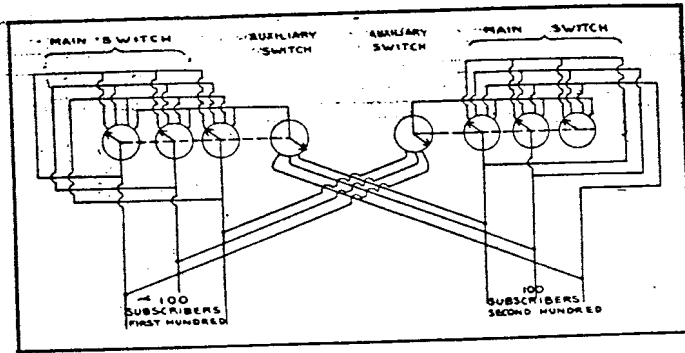


Fig. 46.—Trunking Arrangement for Small Exchanges.

the plan shown in Fig. 46, for small exchanges. According to this plan the main switches will contain the contacts for the lines in their own group, and, in addition, one set of contacts leading to an auxiliary switch which trunks to the other hundred. Thus we have 50 per cent trunking within the group, but only 1 per cent between groups.

The system of Moise Freudenberg, which was applied for patent Jan. 10, 1896, depended on his previous system, to which reference has already been made. There was to be a plate, Fig. 47, *A* containing as many terminals as subscribers' lines, and to which they were connected. Over this plate a wiper *W* was adapted to move by separate impulses of magnets in different directions. The inventors claimed to be able to use movements in any two directions, as well as radial and rotary. This flat-plate form, with the two movements at right angles, reminds one very much of the system of the Erickson Brothers, which they brought out in 1893, before going with the Strowger Company. (See patent No. 616,714.)

As originally planned, each subscriber in the Freudenberg system was to have one of these plate switches. Observing the waste of apparatus, he arranged the scheme of Fig. 47 to enable any subscriber to use any switch and cutting down the number of switches to that which would handle the traffic.

B, B, etc., are metallic wagons or carriages running on rails *C C* with which they made contact. Each wagon had its own insulated track, which was connected to a particular subscriber's line. Just under the tracks and at right angles to them were a number of metal beams *D D*, each connected to a plate switch. When any subscriber desired a connection he, by electrical

means, started his wagon out to hunt a beam. A projection on the under side of the wagon hit the first idle beam, made electrical connection with it and swung it down out of reach of any other wagon. The plate switch to which this beam was connected was now at the service of the subscriber, the lines of all subscribers being multiplied to all the switches. If any other

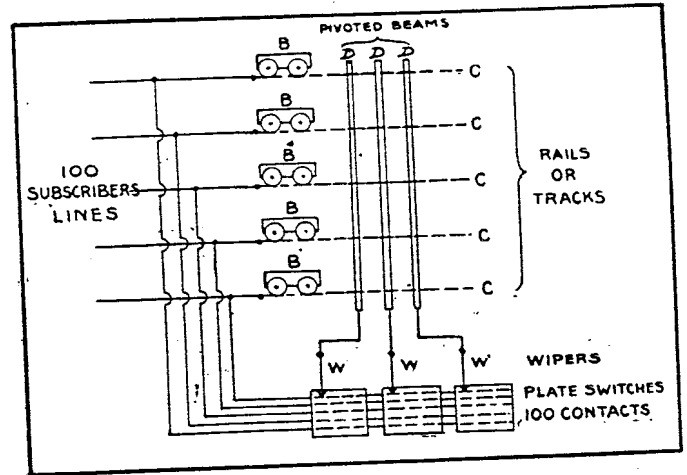


Fig. 47.—The Freudenberg System.

subscriber desired a connection, his wagon would pass over the depressed beam of the switch which was in use and avoid interrupting the other party.

This reminds one somewhat of the present line switch, which gives all the subscribers in a group access to any one of a small number of first selectors, though the method of doing it looks crude now. The tendency seems to have been to get away from mechanical devices and do things electrically. And the writer believes that this is a move in the right direction, though it may be carried too far, resulting in an undue electrical complication for the sake of mechanical simplicity.

16. First telephone trunking system

In the summer of 1896, A. E. Keith, John and Charles J. Erickson began work on a new line, that of devising a 1000-line board without making a 1000-line switch. This they accomplished by a general plan very much like that of J. G. Smith, though the form of switch with which they had to deal was different. Fig. 48 shows the scheme of wiring, in which the switches shown at the left are the same style of connector as had been used at Michigan City, Ind., and elsewhere, with the plaster of paris bank. At the right, numbered 12, 13, 14 and 15, are groups of "selectors." These are special switches, with 10 vertical steps, but only one rotary. There is one for each subscriber and but one trunk from one group to any other one. Thus any subscriber's line will end at the central office in two places: first, in one of the selectors at the right, by means of which he can call any group and line in that group, and, second, in the bank of one of the connectors at the left, through which calls may come to him from other lines. The selector switches are grouped 10 in a group and 100 groups. The connectors are grouped in 10 groups of 100 switches each.

Fig. 49 shows the selector switch, front and side views. The bank, as shown, is made up of wires like the zither or piano wire-board, but it was drawn this way only for convenience. The plaster of paris bank was to be used. *B'* is the vertical magnet, *F'* the rotary magnet. *PM* is the private magnet. All three magnets are permanently connected to battery. $39L'$ and $35L'$ are the line wipers, while *L'* is the private wiper. The two line wipers are connected to the two springs 29 and 30 which form the side switch. Normally, the wipers are not connected to the lines.

Although Fig. 49 shows the general design of the selector, reference to the simplified diagram of Fig. 50 makes it easier to explain its working. There are also some mechanical movements which must be explained, not being clear in the Patent Office drawing, Fig. 49. The vertical magnet *B'* in addition to lifting the wiper shaft, operates a contact 100 which connects the rotary magnet to the frame. There is also a downwardly projecting hook on the lever which holds the detents away from the ratchet cylinders. The detents are released on the first upward motion of the magnet. The rotary magnet, besides rotating the shaft, operates a switch 101 which normally holds the private wiper *L'* on ground, but may switch it over to the private magnet *PM*.

The side-switch, 29 and 30, is under tension tending to close the contacts 31 and 32, which lead to the lines. The springs 29 and 30 are connected mechanically to the shaft and rotary magnet by means which can only be clearly represented by exaggerating the dimensions of some portions. 104 is an insulating number which connects to lever 105. The four levers 105, 106, 107 and 108 are here represented as in one piece, pivoted at the center. In reality a much simpler lever does the work. Acted on by the transmitted tension of the springs 29 and 30, 106 would move to the right but for the lug 109 on the shaft. When the rotary magnet pulls up, a finger *G'* holds 107 from moving and allowing 105 to close the side switch. If the

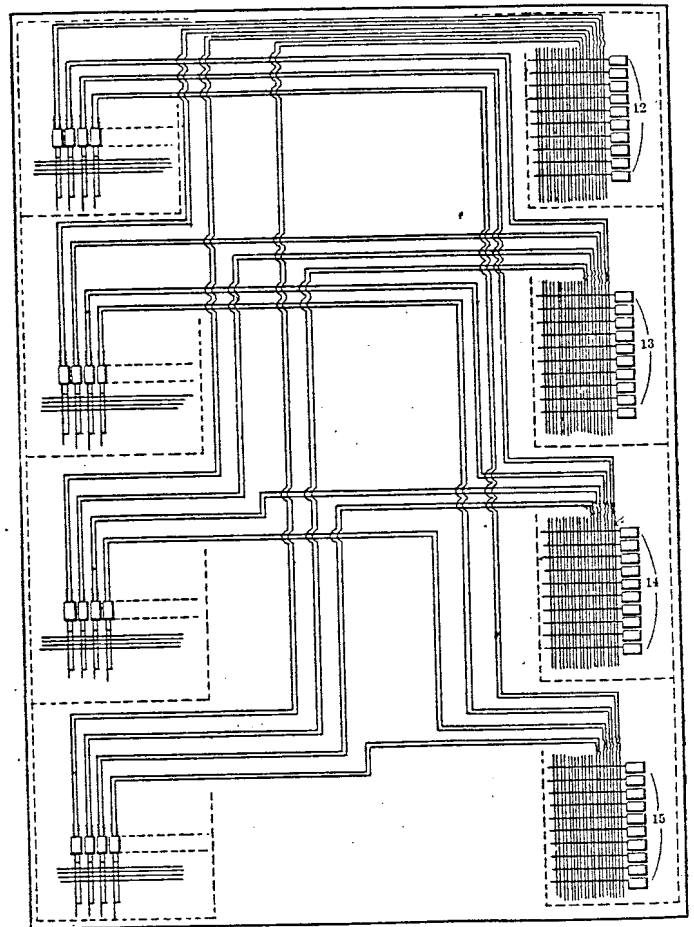


Fig. 48.—Scheme of Wiring Used for a 1000 Line Switchboard.

private magnet be pulled up, its lever 110 prevents 108 from moving and likewise keeps the side switch from operating.

The upper portion of the shaft is equipped with a bent wire 111 adapted to contact the spring 112 on the first upward motion and to break that contact with the first rotary motion. Its function is to connect the rotary magnet *F'* to the line at the proper time.

The operation was as follows: The hundreds digits come in on the vertical line, operating the vertical magnet which steps the shaft up, releasing the detents on the first motion. The upward motion of the shaft brought the bent wire 111 into contact with the spring 112. The tens digits are next pulled, coming in over the rotary line and operating the rotary magnet. On the first impulse the rotary magnet pulls the shaft around one notch, moving lug 109 from lever 106. But the lever *G'*

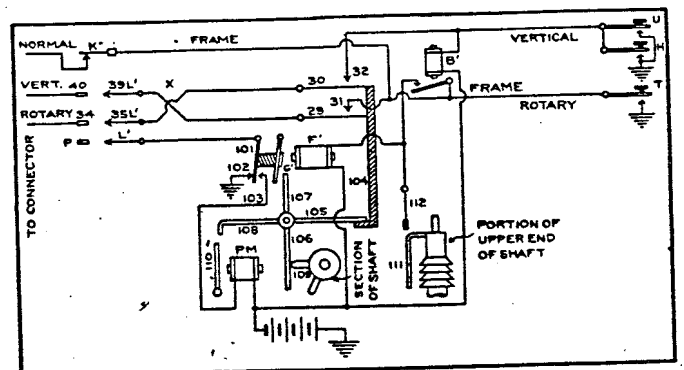


Fig. 50.—Simplified Diagram of Selector Switch.

of the rotary magnet prevents the side-switch from operating until the shaft has rotated far enough to break the contact 111-112. Then the rotary magnet falls back and allows the side-switch to connect the wipers to the lines. All this happens between impulses, so that only the first rotary impulse is lost, all the rest passing on to the vertical magnet of the connector, stepping it up. The units impulses come in over the vertical wire, but owing to the transposition of wires at *X* they arrive at the rotary magnet of the connector. It will be noted that the first tens digit is utilized in switching through the selector; that is, in rotating in the single step. Thus, one 10 would be lost in every hundred, and if a subscriber called 354, he would really move the wipers of the connector in the third hundred up and around to 44.

The private contacts in the bank *P* are multiplied through the particular group of selectors to which a trunk is also multiplied. When a trunk is occupied, the private contact corresponding to it is grounded by the private wiper of the switch which is using the trunk. If another selector tries to get in on the same trunk, the following will happen: When the rotary impulse comes in over the line, it pulls up the rotary magnet and rotates the wipers into contact with the bank. But the instant the private wiper *L'* strikes the grounded contact, 101-103 being closed, the private magnet *PM* pulls up, catching its hook under the end of lever 108. When the rotary magnet releases, 105 can move back a little, but not enough to operate the side-switch, leaving the trunk undisturbed. The rest of the impulses would do no harm.

To release from this condition the subscriber simply hung up as usual. This grounded the vertical, then the rotary, then cleared the vertical, followed by the rotary. When the vertical was grounded it closed the contact 100 connecting the rotary magnet to the line. Grounding the rotary pulled up the rotary magnet, which released the detents, pressing a lever from them under a hook on the lever of the vertical. When the vertical relay was released this hook passed down over the lever from the detents, locking them away from the ratchet teeth. The release of the rotary let the shaft rotate and drop back to normal.

The normal line over which incoming calls to any subscriber are received goes through the off normal switch *K* on the top of the shaft. If the called line is busy by having made a call, this switch will be open and the calling subscriber will notice that his bell rings open, as calling was done by series magneto bells and hand generators.

17. The Automatic Telephone Exchange Company

In the fall of 1896 Almon B. Strowger, the originator of the system, left the employ of the Strowger Automatic Telephone Exchange and went to Florida to recover his health, which had been failing for some time.

On Jan. 28, 1897, the Automatic Telephone Exchange Company, Ltd., of Washington, D. C., was formed for the purpose of carrying on the automatic telephone business. Previous to this incorporation it had gone by the name of "Drawbaugh Telephone & Electric Appliance Company, Ltd., of Baltimore, Md., and London, England." Col. T. W. Tyrer, of Washington, D. C., was the general superintendent and leading spirit, and had associated with him John Bauernschmidt as vice-president, and Joshua Horner, both of Baltimore. It was the purpose of this company to sell the apparatus manufactured by the Strowger company, and with this end in view it entered into agreements with the latter on the date above

mentioned. The Automatic Telephone Exchange Company was to act as United States agent for the Strowger Automatic Telephone Exchange. It was to pay a royalty of \$3 per year "for each switch and outfit so long as such switch and auxiliary device may be in use," and was to install 3000 switches the first year and 2000 additional each year for 10 years. Deferred royalties were to draw 6 per cent.

18. The Augusta System

In February, 1897, the Strowger company commenced installing the last described switchboard at Augusta, Ga. As far as known, this was the first trunking board to be put into actual public use, although it did not possess the feature of automatic trunk selection since there was only one trunk to any group.

The idea of using primary and secondary switches needs to be carefully separated from that of automatically selecting a non-busy trunk. The two are not necessarily the same, though wherever automatic trunk selection is used there must be two

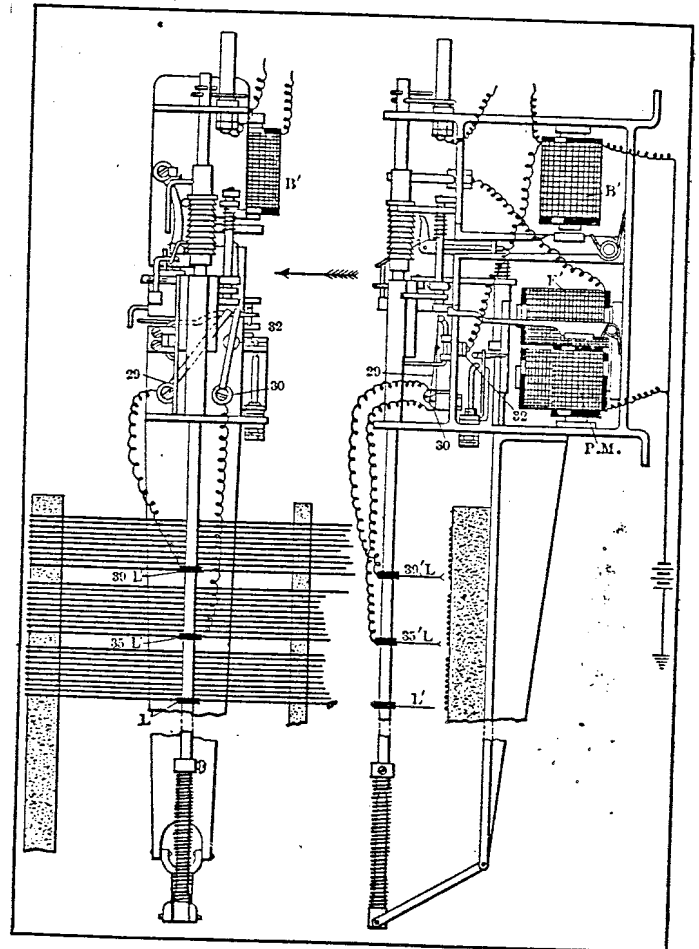


Fig. 49.—General Design of Selector Switch, Front and Side Views.

or more sets of switches. But, as will very readily be seen, the primary and secondary switch idea is of little practical use if we are restricted to but one trunk to each group.

The Augusta plant was completed in March, 1897, and possessed numerous points of interest in addition to the arrangement of switches. There were no wiper cords on the selectors or primary switches. The rotation of wipers to bank is shown

by Fig. 51. The bank contacts were arranged in three groups, each group consisting of two vertical rows of 10 contacts each. All the contacts in the left-hand row, L_1 , were tied together and connected to the vertical wire of the switch to which the bank belongs. The right-hand contact, T_1 , of each pair was attached to the vertical line leading to a connector in a certain group of switches. The middle vertical rows, L_2 and T_2 , were similarly devoted to the rotary line and trunks, and the

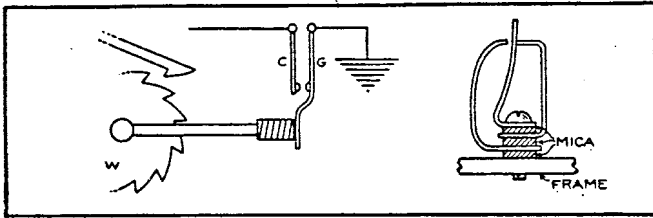


Fig. 52.—Arrangement to Separate Accidental Grounds on Line from Grounds Occuring in the Sender.

right-hand rows, L_3 and T_3 , to the private. The wipers were U-shaped and when normal, rested where shown in the front view. If the shaft were lifted one notch and rotated one notch all the wipers would occupy the lowest row of contacts. In this position the vertical wiper V would connect together the two bottom contacts in rows, L_1 and T_1 , thereby projecting the vertical line of the subscriber into connection with the vertical trunk to the first group of switches. The rotary wiper, R , also connects the rotary line to the rotary trunk by connecting the two bottom contacts in the L_2 and T_2 rows, while the private wiper, P , does the same for the private line. The wipers were made of two springs, as shown in the detail portion of Fig. 51, which shows end and side views with the wiper off and on contact. While moving vertically to reach the desired level the ends of the wipers were between the vertical rows, but not touching them, as seen in the plan.

The dial which was used was very much like that which had been invented and developed during the spring and summer of 1896, covered by patent No. 597,062. However, there was no indicator to show the order of the digit pulled, as it was considered a needless complication. The speed governor was a centrifugal affair instead of the weighted pallet escapement which was described. It worked more quietly and gave better regulation.

The dial proper carrying the finger holds was attached to its shaft by a cone fit, being held on by a machine screw in the center of the end of the shaft. The dial was insulated from the shaft by a layer of fiber to remove any possibility of subscribers getting shocks. The friction of this cone was not sufficient to prevent the dial from slipping, resulting in the user getting wrong numbers. To remedy this defect the cone end of the shaft was covered with shellac and paper and the dial forced on again over it. This stopped the slipping, though it made the removal of dials more difficult.

The ground connection was not wired permanently to the mechanism of the sender, but was carried to an insulated spring, as shown in Fig. 52. W is the star wheel, which carries a lever with insulation on the end. When the sending device is in its normal position, the receiver being on the hook, this insulated end bears against the ground spring and keeps it clear of the circuits. But the first motion of the dial pulls the star wheel to the left and allows the ground spring, A , to touch the spring, C . This arrangement was made to enable the separation of accidental grounds on lines from grounds occurring in the sender. If a line acted as if grounded, but only while calling, it was almost sure to be in the subscriber's instrument. For ground this system did not depend on the earth, but used a common return.

Since the magnets, each of 16 ohms resistance, were directly in the line, the line current had to be relatively heavy. In the case of the longer lines it took as high as 96 volts to force the required current (1 amp) through the resistance. As this was too high a voltage for the shorter lines, taps were taken from the battery at various points, giving three voltages be-

side the maximum. Even this was not close enough regulation and resort was had to the insertion of additional resistance in each of the shorter lines to even them up with the longest lines in their particular voltage group.

In Fig. 53 are shown the conditions which existed for one connection through the board. Each subscriber's line appeared to be metallic, and such they were from the substation to the office. But, in the switchboard, one side of each line was tied through a magnet to negative battery. The other side was carried to the wiper with no attached connections, and given a clear connection through to the called line. This arrangement produced cross-talk, but as the telephone-using public had not been educated by the quietness of a clear metallic circuit, there was no noticeable dissatisfaction. The arrangement of common return wires is also indicated by broken lines. It occasionally happened that two of these common return voltage feeders got crossed, which resulted in running down that portion of the battery which was between them. "American" storage battery was used, this being, as far as is known, the first public automatic exchange using secondary battery.

As might be expected, the heavy current used to operate the switches gave trouble by arcing at the make-and-break point in the substation sender. Occasionally the heat was great enough to take the temper out of a spring. There were no platinum contacts in the telephones, but the switches were equipped with them. For this reason there occurred dirty contact troubles in the talking and ringing circuits which could not be charged to the automatic system. Where platinum was used in the switches it was soldered on—not riveted as is the present practice.

Some of the lines running to Summerville were $3\frac{1}{2}$ or 4 miles long, and on these special magnets of 70 to 80 ohms resistance were used. These more sensitive magnets had to be used, for it was not thought advisable to run the voltage any higher than the 96 volts. In November, 1897, a line was run to the canal locks, $7\frac{1}{2}$ miles out. For this a ground return was used. As it was impossible to make the magnets work over this line, relays were installed to operate the magnets on a local circuit. This is one of the first, if not the first, case of using line relays on an automatic board in practical public use.

The mechanical construction of the switches was somewhat crude. Soldered joints were used to connect certain parts where a solid piece should have been made.

The rudimentary side switch, which controlled the private wiper, was simply a combination of one movable vertical spring between two fixed springs, all held by one screw and insulated from one another by bushings and mica plates. (See

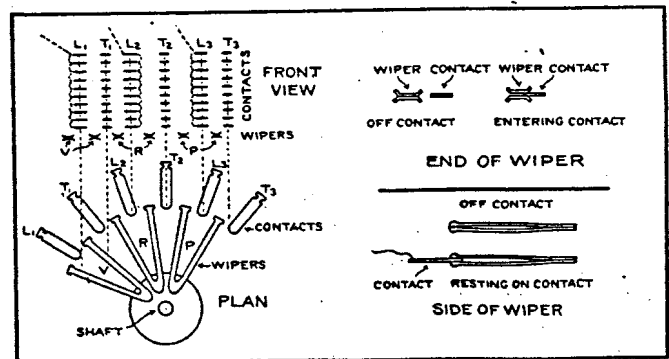


Fig. 51.—Details of Wipers, Showing Method of Rotation to Bank.

right-hand diagram, Fig. 52.) The mica insulation used to separate the springs often broke down. This was probably due to the use of acid in soldering connections to the springs. In other parts untreated fiber was used, which gave trouble by absorbing moisture. This is now avoided by boiling out in paraffine and beeswax and not using fiber for any large parts.

As the frames of the switches formed one side of the cir-

cuit they were all insulated from one another and from the supporting frame.

It was asserted by some who worked on the board that in certain cases magnet coils became defective through electrolysis, since the wires showed a corroded appearance. But this doubtless should be charged to the use of acid in soldering, for it is well known that such results are very likely to follow its use. Some trouble was caused by the friction of the shafts,

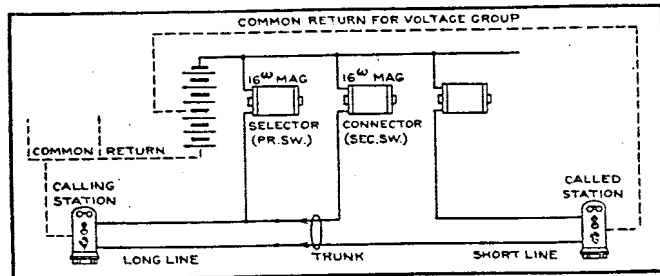


Fig. 53.—Diagram Showing Conditions Existing for One Connection Through the Switchboard.

which was sometimes so great as to prevent them from dropping clear down on the release.

The total capacity of this board was 900 lines, but only 400 were installed. The equipment was later increased to 600.

This exchange is most noteworthy in that it was the first public installation of the first successful attempt made by the Strowger engineers to get away from the single switch idea. Manual switchboards had been developed on the idea of the multiple, which makes it possible for the operator who answers a call to reach over the terminals of the entire exchange and select the called line. If we substitute for the human operator a switch with the proper number of wipers and for the section of multiple jacks place the bank of contacts, we shall have the type of automatic switch which had been used up to that time.

The forerunner of the manual multiple switchboard was the transfer board, in which the operator who answered a call trunked it to the position on the switchboard in which the called line appeared. It was relatively cheap in first cost, but slow in operation, since the concerted action of two operators was necessary to complete the circuit. If we substitute for the answering operator a selector switch, which can select the desired group, and for the second operator place the connector switch, which can select the line in that group, we shall have the idea underlying the Augusta board. Like the transfer board, it is cheaper in first cost. Unlike the transfer board, it is just as rapid as the older single-switch systems. The reason lies in the uniform rapidity of the mechanical and electrical actions, which are not subject to the varying delays which beset human beings. The automatic selector will get a trunk in a certain period or it will not get it at all. There is no guessing about it after a reasonable time has elapsed.

In March, 1897, Mr. B. G. Dunham began his work for the automatic people at Augusta, Ga. Mr. Dunham was an Iowa man, and had graduated from the Iowa State College at Ames, having taken the electrical engineering course.

The Augusta board showed that the principle of trunking is the correct one for automatics. The next problem attacked was how to get more than one trunk to each hundred. Evidently it would be easy to provide the selector switch with several contacts in each row, each contact representing a trunk line, all lines of a given level running to the same hundred. There each would terminate in a connector switch. If, on stepping a selector switch up to the level of the desired hundred and rotating it one notch, the first trunk proved to be busy, the switch wipers could be rotated another notch, or another, and so on until a non-busy trunk was secured. Although this sounds easy, it proved to be a difficult problem. One of the principles of automatic design which had by this time become clearly established is that the subscriber must not be expected to do things which will call for any degree of knowl-

edge of the system. The system must be so arranged that any person of sound mind can operate it correctly on the first trial after reading simple directions. This principle restricted the selection of a non-busy trunk to such means as could be had from the regular operation of the dial and, of course, it was seen that the subscriber could not be called upon to assist consciously in operating that.

In June, 1897, the engineers of the Strowger company made their first experiments with a means for non-busy trunk selection. They proposed to insert in every number a "0" just after the hundreds digit. Thus, the number 248 would appear in the directory as "2048." The hundreds digit was to lift the wipers of the selector to the proper level corresponding to the proper hundred. The "0" digit was to give 10 rotary impulses to the selector shaft. On reaching the first non-busy trunk the current was cut off, so that the remaining impulses did no harm. The last two digits were to operate the connector the same as in the Augusta board.

19. Company Organization

The preliminary contracts of January, 1897, between the Strowger Automatic Telephone Exchange and the Automatic Telephone Exchange Company were followed by another contract signed Aug. 10, 1897. The former company now devoted itself more actively than ever to development, and during the fall of 1897 and spring of 1898 made up a number of exhibit boards which could be used to demonstrate the system and get business. One of these was equipped with a number of trunks between groups, the selection of the non-busy trunk being made by the "0" scheme which has been described. Another way of securing this selection had been considered, and rejected as not practical. It was to have the interrupted battery current furnished by a machine at central, instead of doing it by the extra motion of the dial. But because of the necessity which this would impose of running the interrupter machine all the time, it was considered impractical. One of the exhibited boards had the magnets bridged.

January 27, 1898, another contract was signed between the Strowger company and the Automatic Telephone Exchange Company, relating to manufacturing by the former and the operation of exchanges by the latter.

March 12, 1898, Mr. A. E. Keith started on a trip to Europe in connection with foreign royalties. He took with him some exhibit boards and showed their operation in London.

In June, 1898, a 400 line board was installed at Amsterdam, N. Y., replacing the 200 line board which had been installed in May, 1896.

As a beginning of its operating projects, the Automatic Telephone Exchange Company, of Washington, D. C., a subset part of its United States territory. October 8, 1898, a contract was given to the New England Automatic Telephone Company for operating the Strowger system in New England. December 16, a similar contract was given to the Pacific Automatic Exchange Company.

20. The 1,000 line system

November and December, 1898, were occupied by the Strowger company in redesigning the 1000 line system. The side switch, that most important adjunct to the modern selector and connector, was invented at this time. It was the outgrowth of the need for collecting the several auxiliary operations into one compact group, controlled with certainty by a single magnet. Its beginnings we have already seen.

Another important change was the switching of both line wires instead of one as formerly. The motor magnets (vertical and rotary) were still in line, but were bridged, so that the talking circuit was perfectly balanced. Relays were

used in disconnecting. The bank was divided into three parts, 100 contacts for the private, 100 for the vertical lines, and 100 for the rotary lines. As many of these features will appear in the New Bedford board, they will not be further described here.

In settlement of some difficulties which had arisen between the two companies, another contract was signed January 1, 1899,

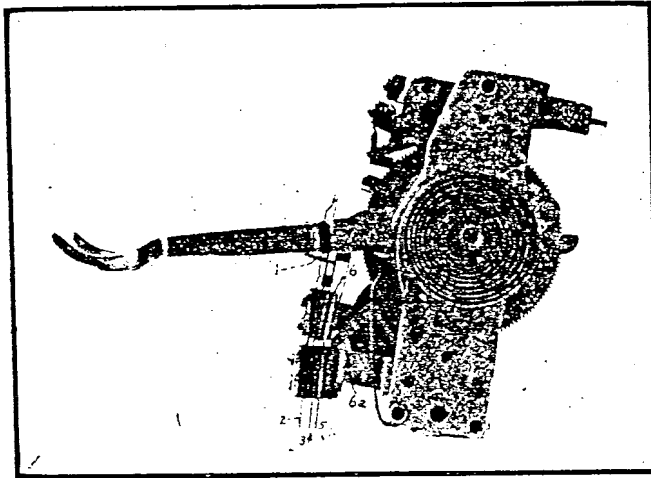


Fig. 54.—Front View of Sender with Hook Down as if Receiver Were On It.

In this contract the question of royalties was adjusted. But the two companies seemed not to be able to do business with mutual satisfaction, for the Washington company brought action in court against the Strowger company. The suit of the Washington company was settled out of court by agreements signed June 9, 1899, by which the Automatic Telephone Exchange Company was to run the entire business, including manufacturing. The Strowger company agreed to turn over all business and correspondence to the Washington company and gave it an option on the foreign patents, but retained the right to use automatic switches in Cook county, Ill. The Automatic Telephone Exchange Company dismissed its suit, and assumed liability for the Strowger lawsuit.

In accordance with the above, on June 21, 1899, the Washington company took charge of the factory at Chicago.

The Strowger company having secured a contract for a board to be used in Berlin, Germany, spent the summer of 1899 building a 400 line board to fill the order. In August and September the board was shipped. It had automatic trunking by the "0" scheme. In October Mr. E. A. Mellinger and R. R. Landon started the installation of the board, which was cut into service in May, 1900. This board served till 1903, when it was replaced by a larger board of a later type.

In October, 1899, Mr. B. G. Dunham, who had been at Augusta, Ga., with the automatic plant of the Augusta Telephone & Electric Company, began work for the Automatic Telephone Exchange Company.

The engineers of the Strowger company continued to work on the problem of the automatic selection of non-busy trunks, which was then the great necessity. In November, 1899, they produced a successful selector with a machine rotary, so that it was not necessary to insert the "0" in the number. A small exchange was built, and operated in the office of the company in November, 1899.

December 17, 1899, the Automatic Telephone Exchange Company moved the factory to Baltimore, Md., having found that it was not possible to work at a distance with any satisfaction. But in the end the Washington company gave up the struggle, and sold everything back to the Strowger company. This took place June 6 and 9, 1900. The factory was moved back to Chicago on June 30.

In the time that the Automatic Telephone Exchange Company had been doing business it had installed interior exchanges at Washington, D. C. in the White House, the Coast and Geodetic Survey, the Times Building, and the Bliss Building, and also at Yuma, Ariz. In December, 1900, the company failed and went into the hands of a receiver.

In the year 1900 the Strowger company began making its own improved transmitters.

Mr. B. G. Dunham, who had been transferred from the Washington company at the time of the final settlement, left the latter company in the last part of August, 1900, to take a position in the automatic plant at Augusta, Ga.

21. The New Bedford System

The year 1900 is marked by the production of the switch-board for New Bedford, Mass., which embodied for the first time in a public exchange the principle of automatic trunking. It had a 10,000-line ultimate capacity, and employed first selectors, second selectors, and connectors. There were, however, only four thousands installed, each having 900 lines.

The substation sender is shown in Figs. 54, 55, and 56. Figure 54 is a front view, with the lever down as if the receiver were on the hook. The dial proper has been removed, but the cone on which it fits may be seen at the center of the spiral spring. The springs of the hookswitch are 2, 3, 4, 5 and 6. The piece 1, making contact with 4, is insulated from the exposed portion of the hook, but connected electrically to the frame. The piece 6a, connected to 6, extends toward the dial shaft, so that in its normal position a pin on the dial tooth wheel rests against it.

Figure 55 shows the rear of the sender, with the hook up; 12, 13 and 14 are the release springs; 15 is the detent for the star-wheel, *S. W.*, and 16 is the pin on the hook lever which operates the release of both star-wheel and springs. Just at the left of the release springs a portion of the governor is visible.

The reverser, 29 and 30, is made of two disks mounted on the dial shaft, but insulated from it and from each other. Each has half its rim cut away so that, in the position of rest, spring 28 rests on 29, and 27 on 30. But when the dial is turned by the act of pulling a digit, the two spring contacts are reversed, 28 resting on the edge of 30, and 27 on 29. Spring 31 makes contact with disk 29 at all times. There is

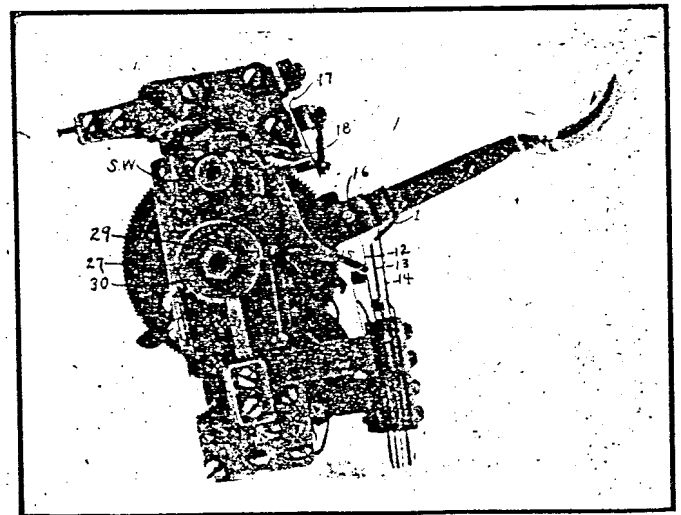


Fig. 55.—Rear View of Sender with Receiver Off of Hook.

a spring, 32, which makes constant contact with disk 30, but as photographed it is hidden by spring 31.

Figure 56 shows the mechanism in the act of pulling the first digit. The arm carrying the pawl, *P*, is rigidly attached to the dial shaft. The pawl acts on the star-wheel, *S. W.*, moving it one notch for each pull. The reverser is shown in action.

The ground is wired to spring 17. When the hook is down and before the first digit is pulled (Fig. 56), the detent 15 rests on a tooth of the star-wheel, *S. W.*, as shown. The insulated head of 15 presses the ground spring, 17, away from the contact, 18, the latter being the common ground connection for all the instrument wiring. But on pulling the first digit (Fig. 56) the detent falls, allowing the ground spring to touch contact 18.

The complete wiring of the substation is shown in Fig. 57, all parts being numbered to correspond to the three preceding illustrations. The talking set consists of a local battery primary circuit, with transmitter, battery, and primary of induction coil wired to springs 2 and 3 of the hook, and the secondary circuit, composed of the receiver and the secondary of the induction coil, wired from the rotary line to spring 7 of the ringing key. This is normally in contact with spring 8, which goes to spring 5 of the hook. The bell is connected from the rotary line to spring 4 of the hook, which normally connects through contact 1 to the frame, returning through pin 24, spring 26, spring 28, disk 29, spring 31, to vertical line. The rotary line is thus the common terminal for the bell and receiver circuits, while the vertical line is switched from bell to receiver by the hook.

In making a call, the receiver is taken from the hook, switching the bell out and the receiver into circuit. The receiver has its circuit completed to the vertical line over the following path: 7, 8, 5, 6, 6a, dial, frame, star-wheel, 24, 26, 28, 29, 31, to vertical line. When the dial is rotated on the first digit, contact 6a is broken, disconnecting the vertical and rotary lines from each other. The spring, 19, of the dial tooth wheel does not make contact on this motion. As the reverser, 29, is on the dial shaft, it also moves to the left the same angular amount. At the same time pawl *P* (Fig. 55 and 56) drop into a notch, grounding 18, also removing pin 24 from spring 26 and causing pin 21 to touch spring 25. Now, as the dial clicks its way back, opposite to the arrow, spring 19 makes a series of contacts grounding the vertical line over the path from dial to frame, *S. W.*, 21, 25, 27, 29, 31, to vertical line. Just before the last impulse, the reverser, 29, changes connection so as to bring the impulse to the rotary line.

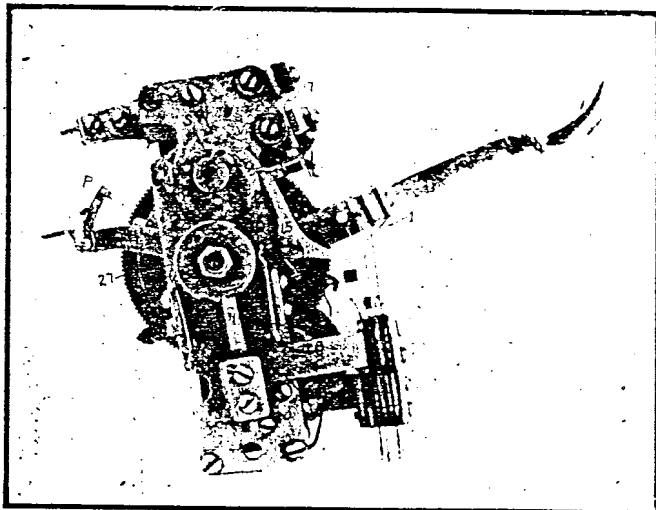


Fig. 56.—Mechanism of Sender as First Digit Is Pulled.

The second and third digits are pulled in the same way, the impulses coming over pins 22 and 23, respectively, of the star-wheel, since each pull of the dial rotates the star-wheel on notch. When pulling the fourth digit, the star-wheel is pulled so that pin 23 is cleared from spring 25 and pin 20 is made to rest under spring 26. This makes the series of impulses go in over the rotary line, ending up with a single impulse

on the vertical. The reason for this will be made evident in connection with a discussion of the switches at central.

To ring, the ringing key is pressed. This connects the bell across the line and grounds its center through 2000 ohms, cutting out the receiver while so doing.

To release, the receiver is simply hung on the hook, causing

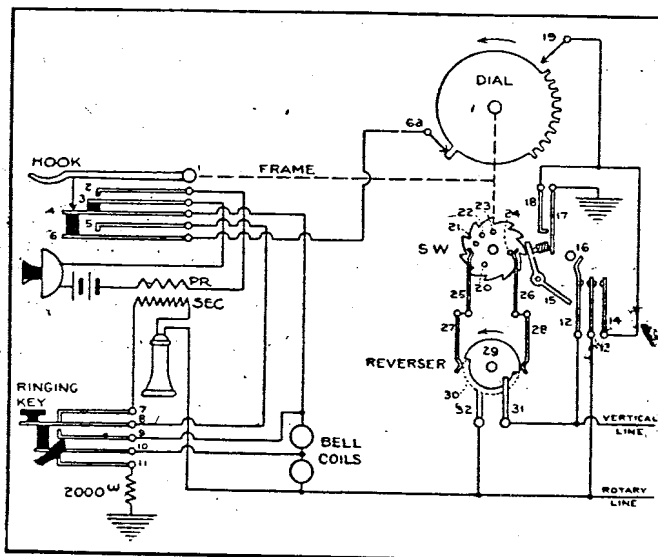


Fig. 57.—Complete Wiring Diagram of Subscriber's Set.

pin 16 to move downward. This momentarily closes together all three springs, 12, 13, and 14, short-circuiting and grounding both vertical and rotary lines. Pin 16 also presses detent 15 away from the star-wheel, *S. W.*, allowing it to snap back to its original position by the force of a spring, 17, off contact 18, thereby freeing the apparatus from ground.

To sum it up in a few words, the functions of the sending device are as follows:

1. Switch the talking and ringing circuits as in any local battery telephone.

2. On operating the dial, disconnect the receiver circuit and ground the lines according to the following code:

First digit,	V. Line — — — — —	R. Line —
Second digit,	V. Line — — — — —	R. Line —
Third digit,	V. Line — — — — —	R. Line —
Fourth digit,	R. Line — — — — —	V. Line —

3. Ring by connecting the bell across the line instead of the receiver, and ground the center of its windings through 2000 ohms.

• Release by dead grounding both vertical and rotary lines momentarily, and resetting the star-wheel.

The New Bedford first selector is shown in diagram in Fig. 58. Two relays, a vertical and a rotary, are placed in series with the subscriber's line. They are of low resistance, 30 ohms, and shunted by a 150 ohm non-inductive resistance to permit the passage of talking current with as little impedance as possible. Each normally draws its current from battery through one of the two 500 ohm ringing relays.

The vertical relay controls the flow of current through the vertical magnet, the latter having for its duty the lifting of the wiper shaft carrying the private, vertical, and rotary wipers. The rotary relay controls the rotary magnet, the function of which is to rotate the wiper shaft. The two line relays each carry an auxiliary contact leading to the release magnet. If the line relays (vertical and rotary) are operated simultaneously, the release magnet will be energized, pulling the vertical and rotary detents from the ratchet cylinder.

The side switch has four members, numbered 1, 2, 3, and 4. In the machine all four are mounted compactly in one place, although in the diagram, for the purpose of simplifying the drawing of the circuits they are separated. Each is shown in its initial position.

"S" is the end of the side switch lever and rests in the angle of spring A, attached to the armature of the private magnet, P. A spring tends to move the side switch lever, S, to the right, as indicated by the arrow, and if allowed to move would switch all the members to their second position. The private magnet is connected to the private wiper, and also to spring 4 of the side switch, so that it is normally grounded.

"F" is a finger extending from the armature of the rotary magnet, and is so adjusted that when the latter is energized the finger presses upon and operates the armature of the private magnet.

The interrupter is kept running by a small motor. The off-normal switch is operated by a finger on the wiper shaft, so that when the shaft is down in its normal position the contact is pressed open. Only one upward impulse is required to close this contact. The vertical and rotary normals are the lines from the connector banks over which calls come to this line. The private normal occupies a contact in the private

bank of the connector switch and it corresponds in position to the vertical and rotary normals.

In making a call, the first digit is sent in by grounding the vertical line a number of times, followed by one impulse on the rotary line. The mechanism for accomplishing this has been described previously. The vertical impulses energize the vertical relay, which in turn pulls up the vertical magnet, lifting the wipers to the desired level. The off-normal switch places battery on the private normal, to keep others from calling this line. The rotary impulse results in operating the rotary magnet once, this rotating the wipers as far as the first trunk line of the level at which they stand. At the same time the finger, F, of the rotary magnet operates the private magnet armature, stepping the side switch over to its second position. This causes a number of changes. At 1 and 3 it cuts off the 500 ohm ringing relays and the normal lines, and connects the vertical and rotary lines directly to the wipers. At 2 it cuts off the rotary magnet. At 4 it switches the private magnet from ground to negative battery through a 500 ohm

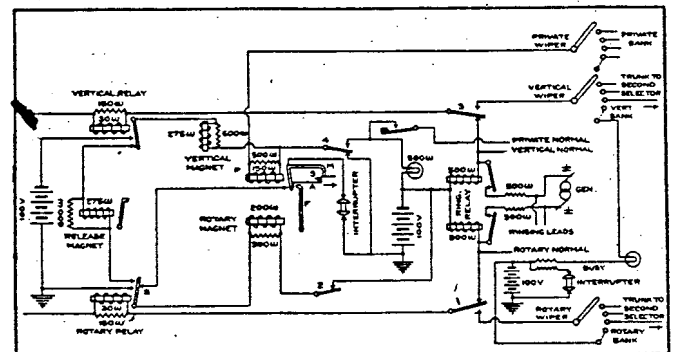


Fig. 58.—Diagram of the New Bedford First Selector.

lamp. This last places the "busy condition" on the private contact corresponding to the trunk which has been taken, so that no other first selector can stop there. Negative battery is the "busy condition."

If the first few trunk lines had been busy, the procedure would have been as follows: The rotary impulse would rotate

the wipers until they made the first contact, the rotary magnet finger, *F*, also pressing the private magnet armature. This allows *S*, the side-switch lever, to slip over the shoulder of spring *A* and strike the solid piece, *M*, which keeps it from moving farther. This slight motion is not sufficient to affect the side-switch members. Contact *C* is also closed. Since the first trunk is busy, its private contact will be "alive" with negative battery, and the private magnet will be locked up.

When the rotary relay falls back after the single impulse, its back contact, *B*, closes the rotary magnet circuit. The interrupter now gives pulsating current to the rotary magnet, causing it to step the wipers around. At every impulse the rotary armature finger holds the private magnet armature, while the private wiper slips from contact to contact. Between impulses the current in the private magnet holds it up so that the side-switch can not operate. But when a non-busy trunk is finally found, there will be nothing on its private contact. Hence the private magnet will have nothing to hold it up—the armature will fall back, breaking contact *C*, and allowing the side-switch to snap into its second position.

The call has now been trunked to a second selector, shown in Fig. 59. This is identical with the first selector, except that the 500 ohm ringing relays are replaced by 500 ohm retardation coils, and there are no normal lines nor off-normal switch.

The connector, Fig. 60, necessarily differs somewhat from

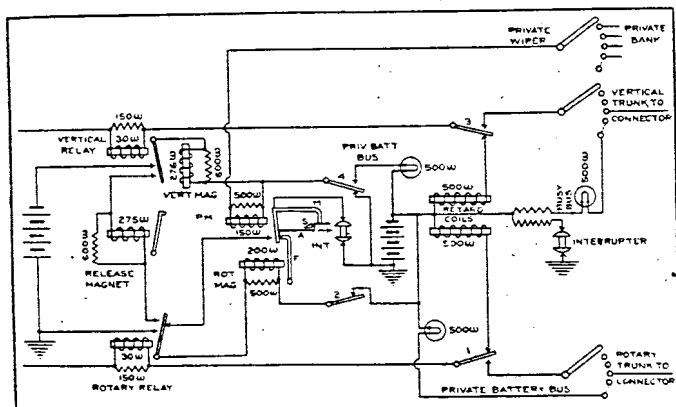


Fig. 59.—The Second Selector, New Bedford Automatic Exchange.

the selectors in that it has no trunk selection to make, the vertical and rotary steps corresponding to the last two digits in the call number. There is no finger on the rotary magnet. There is a small rod, *R*, attached to the vertical magnet armature, which extends through a hole in the solid arm, *M*, of the private magnet armature and the light spring, *D*, terminating in an adjustable head, *H*. The private magnet armature is shown in its normal position, close to the magnet. There is a feather cam on the wiper shaft which prevents the armature from moving away from the private magnet until the shaft has rotated at least one notch. A second cam is arranged to press the pawl of the vertical magnet away from the ratchet cylinder when the shaft has been rotated one notch or more.

The operation is as follows: The impulses for the tens digit come in over the vertical line, and lift the wiper shaft. The above mentioned cam prevents the private magnet from being disturbed. The single rotary impulse moves the shaft around one notch without causing the wipers to engage any contacts. The units impulses come in over the rotary line and rotate the wipers to the desired contact in that level. The last impulse comes in over the vertical line, energizing the vertical relay and magnet once. The second cam mentioned above prevents this from acting on the shaft, but through the rod, *R*, it pulls on the spring, *D*, and lifts the solid piece, *M*, letting the side-switch snap over into its second position. The side-

switch thus connects the vertical and rotary lines to the called line, and performs the same other switching as in the selectors.

The calling station now has its lines extended to the first selector of the called station, arriving at that point over the normal lines. This leaves nothing across the line except the two 500 ohm ringing relays in the first selector of the called station. To ring, the ringing key at the calling station is

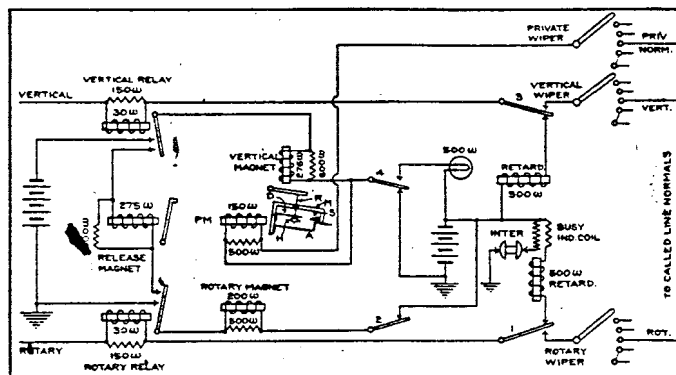


Fig. 60.—Diagram of the Connector Circuit.

pressed. As before described, this connects the bell across the line (in place of the receiver) and grounds the middle of the bell coils through 2000 ohms. The whole scheme is shown in Fig. 61. As will be clearly seen, this causes current to flow from the battery, through the ringing relays, through all the line relays, through both coils of the bell, and to ground through the 2000 ohms. This would pull up all the line relays, *V*₁, *V*₂, etc. (Vertical relays), and *R*₁, *R*₂, etc. (rotary relays), but for the limiting effect of the 2000 ohms resistance. Since the line relays are wound to 30 ohms each, and provided with a 150 ohm non-inductive shunt, they are not as sensitive as the ringing relays, which are 500 ohms. Consequently, the latter alone pull up, connecting ringing current to the line.

A peculiarity in ringing will be noticed in that this caused the bells of both stations to ring. In a way this seemed to be a good feature, as it permitted the calling subscriber to know that something was happening while he pressed the ringing button. This ringing circuit was the invention of Mr. T. G. Martin, then of the Strowger company. In common with most schemes where dependence is placed on the marginal action of relays, it required very careful adjusting to keep the switches working smoothly.

The action of the connector, if the called line is busy, will be seen by reference again to Fig. 60. Imagine the vertical and rotary motions to have been completed, the wipers resting on the called line and its private, and we are ready for the final single impulse which comes in over the vertical line.

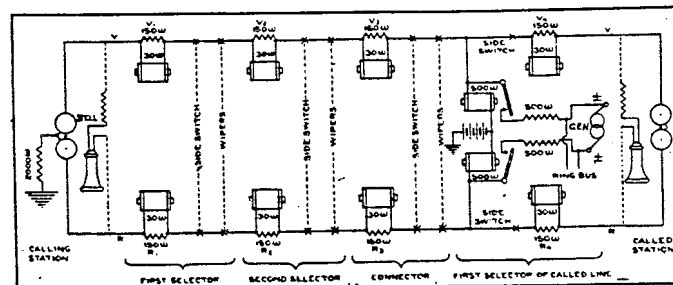


Fig. 61.—Circuit Illustrating the Talking and Ringing Conditions.

The called line being busy its private contact, on which our private wiper is resting, will have negative battery on it. Through side-switch 4 our private magnet is grounded, so that the circuit is completed and battery current will flow through the latter, locking its armature where shown. When the final

vertical impulse comes in, it will energize the vertical magnet and pulling on spring *D*. But owing to the locking current the private magnet will not move, and the side switch levers, 1 and 3, will remain normal, where shown in the figure. In this way the called line can not be disturbed. While listening for the called stations to answer, the calling subscriber will hear the busy tone, which comes in through the two 500 ohm retardation coils.

The talking circuit of a completed connection is outlined in Fig. 61, which has been used to illustrate the system of ringing. It will be seen that there are eight line relays in series, four in each side of the circuit. Each is shunted by 150 ohms of non-inductive resistance, which makes it not quite as bad for transmission purposes as it might be. Yet it seems that it would be bad enough. There are two 500 ohm relays bridged across the line with battery tied to the center and to ground. This makes 1000 ohms of highly inductive resistance, which is entirely permissible and good engineering. There are fourteen contacts between the two subscribers, counting only those in the switches. Six of them are wiper contacts, which may be very good, since they are wiping contracts and may have sufficient pressure to cut through ordinary dust. The remaining eight contacts are in the various side switches, and if made of platinum, as they were, have the possibility of doing good work, though not as good as the modern side-switch, with its wiping contracts.

In disconnecting, the vertical and rotary lines were momentarily grounded by the springs on the hookswitch at the calling station. This action has been described in detail. Since this is a ground through zero resistance all the relays shown in Fig. 61, will be pulled up. As has been shown in connection with the description of the first selector, this will energize the release magnet of each switch, restoring all machines to their normal positions. A mechanical device also resets the side switch by the rotary motion of the shaft.

This system possessed many features in common with the modern automatic. It marked the beginning of modern success, though as yet very imperfect. Two points may be mentioned, points which have been more or less discarded. Each magnet in the switch was shunted by a certain non-inductive resistance. This was to reduce or kill the excessive spark at the contacts of the relay which fed current to that magnet. One hundred volts was the battery pressure used for the operation of the system.

Referring again to Fig. 58, attention may be directed to the busy test wired to the last contacts of the first selector bank. In case all the trunks were busy, the wipers would be carried to this last point, where the busy signal would give the subscriber warning. Moreover, the chattering of this switch would call the attention of the attendant to the fact that something was wrong.

22. The Fall River System

The New Bedford board was installed by Mr. T. G. Martin, work beginning in October and being completed in December, 1900.

In May, 1901, the plaster of Paris bank was discontinued. Though it had served better than the electrose bank, it was still far from perfect. The next move was a bank built up of brass terminals separated by layers of paper. The use of paper

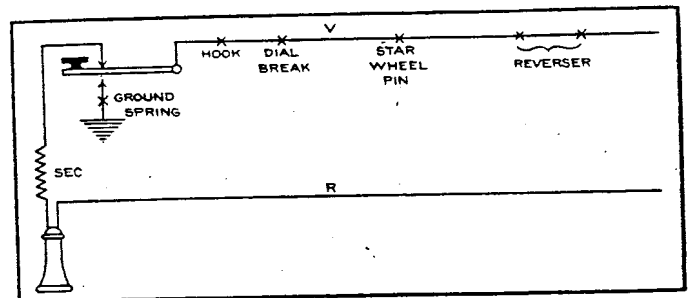


Fig. 62.—Wiring Diagram of Substation Ringing Key, Automatic Exchange in Fall River, Mass.

soon gave way to hard fiber, specially treated to prevent the absorption of moisture.

In the spring of 1901 the present Automatic Electric Company was organized to carry on the business of making and selling automatic telephone apparatus. The Strowger Automatic Telephone Exchange retired from activity, merely holding the patents under which the Automatic Electric Company operated. The personnel of the latter was as follows:

President, C. D. Simpson; vice-president and general manager, J. Harris; secretary and treasurer, A. G. Wheeler, Jr.; general superintendent, A. E. Keith; engineers, A. E. Keith, T. G. Martin, John Erickson, Charles J. Erickson, E. C. Dickenson.

The new organization was not encumbered with the business which had harassed the older concern, and started with a fair chance for success.

In June, 1901, an automatic switchboard was installed at Fall River, Mass. It was of the 10,000-line type and followed quite closely the lines of the New Bedford board. But there were certain distinct improvements which will be mentioned in

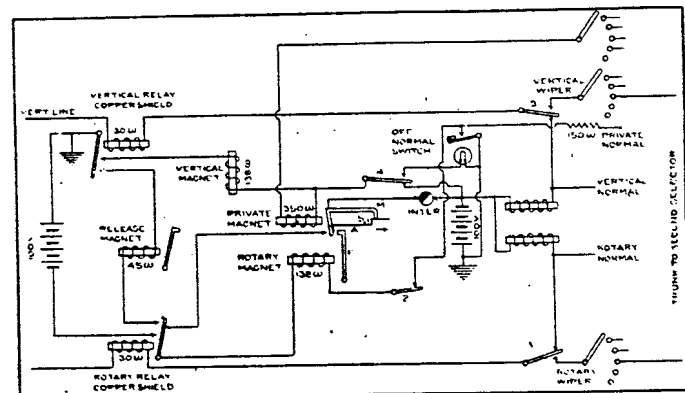


Fig. 63.—First Selector Switch, Fall River Exchange.

detail, as they made Fall River the dating point of the really modern system.

The substation sender had the same mechanism for sending

signals, and operated on the same code with regard to the vertical and rotary lines, namely, the first three digits consisted of a series of impulses on the vertical followed by one on the rotary line. The last digit was reversed, the series of impulses going in over the rotary and ending with one on the vertical line.

The system of ringing was improved so that it required the grounding of only the vertical line to operate the ringing relay, and no resistance was needed. The wiring of the ringing key is shown in Fig. 62, the other substitution details being omitted, since they are exactly like the New Bedford system previously described.

The first selector is shown in Fig. 63, and differs in several points from the New Bedford switch. In the Fall River first selector here shown the general connection plan of battery supply, vertical magnet, rotary magnet, private magnet, and the release is unchanged. But instead of shunting each relay or magnet with a non-inductive resistance, a thin copper tube was slipped over the iron core, and the working coil wound on that. This copper shield had the effect of a short-circuited secondary in a transformer, and took up much of the magnetic energy which would have produced very bad sparking at the contacts which controlled it.

The line relays were wound to 30 ohms with No. 29 wire,

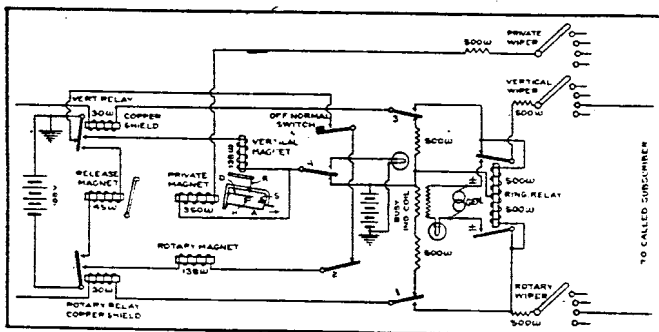


Fig. 64.—The Connector Circuit.

while the vertical and rotary magnets were wound to 138 ohms with No. 33 wire. The private magnet was wound to 350 ohms with No. 36 wire and the release magnet had No. 30 wire to a resistance of 45 ohms.

The rotary magnet normally had no circuit, so that if the rotary line accidentally swung into the ground it would only make the rotary relay click, but not move the wiper. The off-normal switch, which closes when the wiper shaft has made one step upward, completed the rotary magnet circuit.

The "busy condition" in the private bank was made ground, instead of negative battery as before. This made it necessary to connect the private magnet through side-switch 4 to negative battery while feeling for a non-busy trunk. This also throws the interrupter into negative battery instead of ground.

No busy test was provided on the last contacts of the bank, as it was found that it was very seldom that all trunks were busy.

The vertical and rotary normals came in to the inside contacts of side switches 1 and 3 as before, but there were no ringing relays here, their place being taken by a relay on the connector. If the called subscriber desired, he could get away from the calling line by merely operating his dial to call someone else. In so doing he would leave the calling line on the

two 500 ohm retardation coils, through which that line could release.

In the second selector the rotary magnet circuit was completed through the off normal switch and a back contact on the vertical relay, as in the connector, Fig. 64. This is to keep the magnet from being energized while releasing.

The connector, Fig. 64, was greatly improved by the introduction of the ringing relay as shown. During the vertical

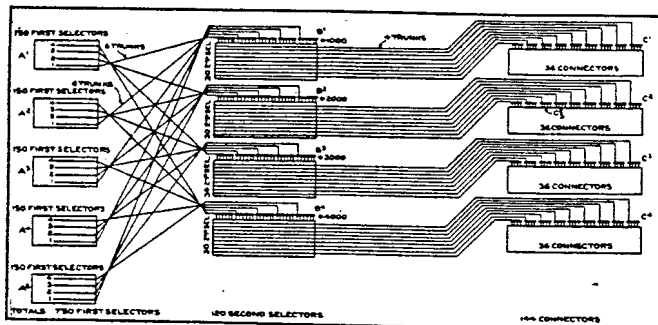


Fig. 65.—Wiring Plan of Fall River Automatic Exchange.

and rotary motions, the lines drew current through two 500-ohm resistances and the contacts of side-switches 1 and 3. When the side-switch was snapped into the second position (by the same means as in the New Bedford board) the 500 ohm resistances were cut out, and their places taken by the two windings of the ringing relay. When the ringing key at the calling station was pressed, it opened the line and grounded the vertical wire. This drew current from battery through all the vertical relays and the V coil of the ringing relay. The pulling up of the vertical relays did nothing. The energizing of the ringing relay broke the vertical line and connected the ringing dynamo to the called line. Thus only the bell at the called station rang. All the troubles of marginal adjustments of the line relays were avoided.

In releasing, both vertical and rotary lines were connected directly to ground at the substation, pulling up all vertical and rotary relays simultaneously. Though this action drew current through the ringing relay, the latter was not energized, as the coils were connected differentially.

The method of operation of the busy tone test on the called line is easily seen from the diagram (Fig. 64) and was substantially unchanged, except that the ringing generator furnished the tone through the induction coil. One peculiarity deserves to be noted. If the called line were busy, the private magnet, finding ground on the private contact, was energized by the resulting current. Though the wipers were resting on the called line, the side-switch prevented any contact thereto. But if the calling subscriber waited until the called line became disengaged, he could press the ringing key and get connection without further operation of the dial. Since the ringing key grounded the vertical line, it would pull up the vertical relay and the vertical magnet. The vertical magnet pawl could not act on the wiper shaft because of a cam, but its armature could pull on rod R and through spring D , lift the rigid lever, M , of the private magnet armature. Allowing the end of the side-switch lever, S , to slip to the right as arrowed, thus moving all the side switch members, 1, 2, 3, and 4. Continuing to press the ringing key would now affect the ringing relay.

The plan of wiring the exchange between switches is shown in Fig. 65. The first selectors were grouped in five groups of 150 switches each, making a total of 750 lines served. There were four thousands provided, 1000, 2000, 3000 and 4000, represented by four groups of second selectors, each group containing 30 switches. Each group was subdivided into five groups of six second selectors each. Each group of six served one of the groups of first selectors, A^1 , A^2 , A^3 . Thus, each first selector in A^1 had only the first, second, third and fourth levels of

its bank wired—the rest were dead. Each of the working levels had six trunks, and each group of six trunks ran to a group of six second selectors in the proper thousand (B^1, B^2, B^3 , or B^4). Each of the trunks terminated in B groups in a particular second selector. The bank of each second selector had nine of its levels wired up, each level having four trunks. Each group of four trunks ran to the proper group of connectors in the thousand to which it belonged. Each thousand had 36 connectors, nine groups of four connectors each. Each trunk of a group of four terminated in a particular connector of a group of four. The banks of these four connectors were multiplied to the same subscribers' lines, so that a calling subscriber could reach the desired station in this group equally well over any one of the four trunks.

The operation was as follows: Suppose some subscriber in A^1 desired to call No. 2348. On operating the dial the first time, his first selector switch in A^1 would be lifted to the second level and automatically rotate until it found a non-busy trunk to B^2 . It would thus gain connection to one of the second selectors in sub-group— B^1 . The operation of the dial for the second digit would lift the wipers of the second selector to the third level, and automatically rotate them until contact was made with a non-busy trunk to the group C^2 . The third dial operation would lift the connector to the fourth level, and the last pull would rotate the wipers to the eighth contact in that level.

An interesting feature in connection with the Fall River board was the connection between automatic and manual systems, though it was not put in at the same time. Fig. 66 shows the essentials of the line and cord circuits. J_2 is the line jack, with a line drop, for the magneto subscriber. The line is wired in the ordinary manner for the three-point jack used. Local calls between magneto subscribers were put up on the regular magneto cord circuits, which are so well understood that they need not be described here.

The special cord for connecting automatic subscribers to those whose lines terminated in the manual board had two plugs, P_1 and P_2 . The former was connected directly to one side of a repeating coil, the center of which was connected through the clearing out drop to battery, the other end of the battery being grounded. The other side of the repeating coil was wired through the listening and ringing keys, K_1 to P_2 , which was designed to be inserted in the magneto jack, J_2 . A special cord was provided for operating the automatic switches. The dial, shown by its two springs and ground, was connected through the listening and ringing key, K_2 , to plug P_1 .

The operator's telephone set was peculiar in the use of one of the key contacts to close the primary circuit. It made it

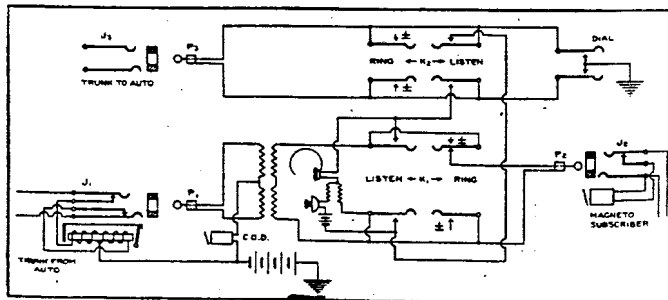


Fig. 66.—Line and Cord Circuits for Connecting the Manual with the Automatic System in Fall River.

necessary to connect one side of all the cord circuits together at the point M , which, it is to be suspected, tended to produce cross-talk.

Incoming trunk lines from the automatic exchange were terminated in jacks and drops, as at J_1 . The jack was of the four-point type, so that the insertion of the plug would cut the drop completely off the line. The drop had at the center of

its winding a tap which was connected to battery. The trunk lines for one-way business to the automatic exchange were terminated in jacks like J_2 .

When a call came from the automatic switchboard, the ringing current from the connector would throw the drop associated with J_1 . The manual board operator, seeing the drop fall, answered with plug P_1 . On getting the number, by means of key K_1 , she would plug into the called line, J_2 , and ring. When the conversation was completed the automatic subscriber would hang up, thereby grounding both sides of the line. This pulled current through both quarters of the repeating coil and through the clearing-out drop, thus giving the manual operator the disconnect signal at the same time that the automatic switches were released.

A call from a subscriber desiring a connection to the automatic system would be received over an ordinary magneto cord. On finding that the automatic board was wanted, the operator would disconnect her telephone set from the cord, leaving it in the jack, J_2 . Inserting the special plug, P_2 , in the outgoing trunk, J_1 , she would operate the dial for the desired number. Ringing was done with the key K_2 , the ringing current not being strong enough to operate the relays in the switches. The special plug was then pulled out, and the connection completed with the magneto cord. On the completion of the conversation the magneto subscriber would hang up and ring off, throwing the clearing-out drop. The manual operator would pull down the the connection and release by pressing a special key which grounded both sides of the line as required.

23. The Chicago System

After the Fall River board, the next important installation was at Chicago, Ill. The Illinois Tunnel Company had secured a franchise for the construction of subways for telephone wires and decided on automatic equipment for the exchange. It was planned to serve only the down-town business district known as the "Loop," bounded by Lake and Van Buren Streets, and Wabash and Fifth Avenues.

The installation of the switchboard was begun Dec. 20, 1902. Switches for 10,000 lines were put in, making the largest single office automatic exchange which had been installed at that date, February, 1903. A certain special requirement was encountered in Chicago which made the work of the automatic engineers more difficult than it had been at New Bedford or Fall River. The Chicago Telephone Co. was offering to the public and operating successfully a measured service on a good common battery manual switchboard. Clearly no flat rate system would do here. The automatic people must meter their calls also. But with their usual energy they had attacked the problem, and were ready with a system which fulfilled their needs. We shall take up the regular operation and features first, discussing the special points as they come up.

The substation sender, with hook and release springs is shown in its normal position in Fig. 67. A portion of the hook lever proper is shown at the right. It is insulated from the framework. Five hook switch springs are shown at 11, 12, 13, 14

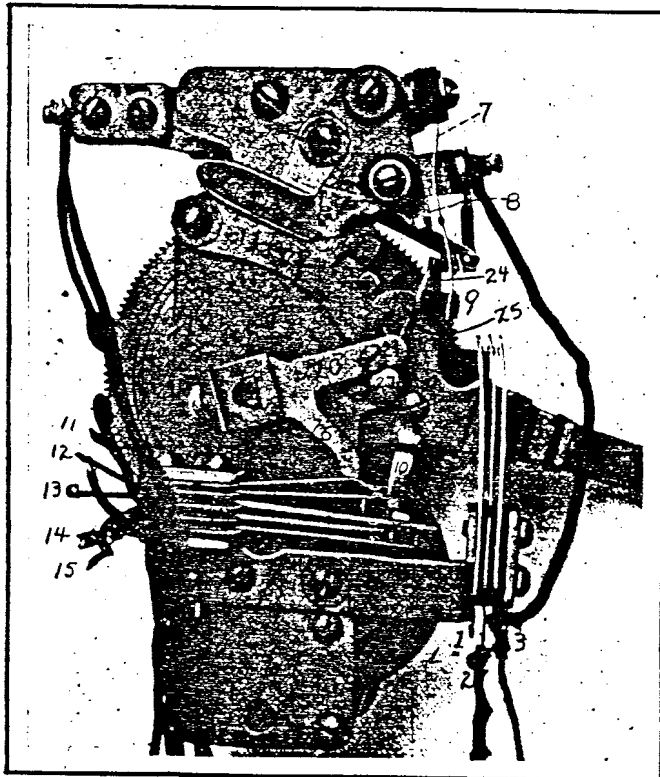


Fig. 67—Chicago Substation Sender, with Hook Down.

and 15. Spring 11 is permanently connected to the frame and carries the vertical line. The lug, 10, on that portion of the hook lever which is connected to the frame, operates the long spring 13, which, through the rubber insulation, also moves the springs 12 and 15, above and below. Attached to the dial

shaft is the curved arm 16, resting normally on the spring 11, acting as a stop for the latter. The straight lever 20 is made in one piece with 16, and carries a pin, 21, whose screw head only can be seen, the pin being on the back of the lever. The force of the dial spring causes the lever 20 to rest against the

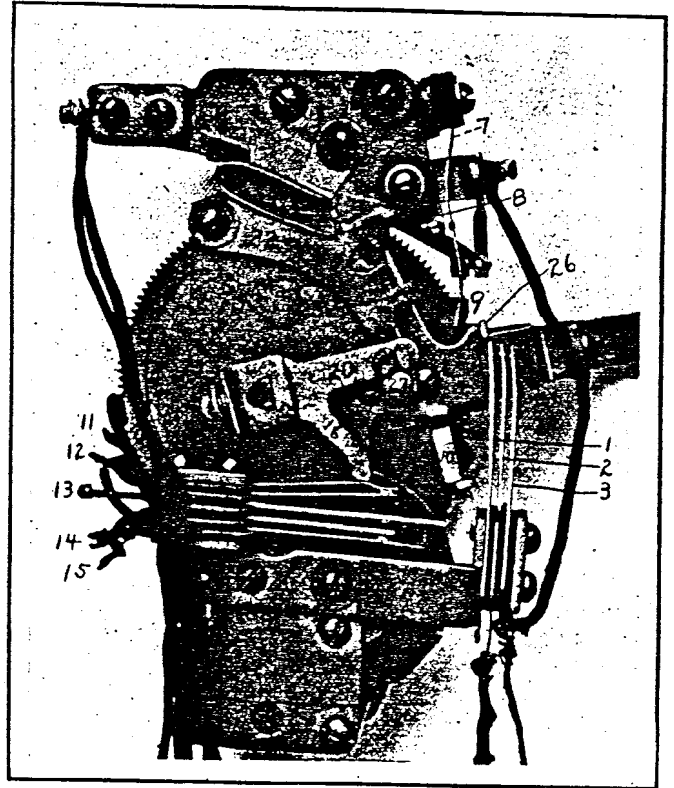


Fig. 68—Condition of Chicago Substation Sender with Hook Up.

stop 27. The irregular shaped lever, 22, is pressed downward by a spring. The lower end of 22 locks the pin 21 on lever 20, so that the dial can not be turned until the receiver is taken from the hook. The provision of this dial lock was another step in the process of making the automatic sender "fool proof." The ground spring, 7, is held from contact with the instrument ground, 8, by the insulation, 9, resting on 25, the end of lever 22.

When the receiver is taken from the hook the lever rises, as in Fig. 68. The lug, 24, on the hook lever pushes on a prong, 23, lifting the irregular shaped lever, 22, so as to unlock the dial. It will be noticed that the springs, 11 and 12, have closed, as have also 14 and 15. Now, when the dial is rotated in pulling the first digit, Fig. 69, several changes take place. The curved lever, 16, has lifted from spring 11, allowing the latter to break its connection with 12, thereby severing the connection from the vertical to the rotary line through the talking set.

Pin, 21, on lever, 20, has lifted lever, 22, so that its end, 25, no longer holds the ground spring, 7, away. This allows 7 to fall into contact with 8, grounding the local instrument ground wire which supplies the impulse springs, ringing button, and release springs. The two impulse springs are not in a position to be shown clearly. The release springs are at the right, 1 being the vertical, 2 the rotary, and 3 the local instrument ground.

tion on spring 1, bringing all three springs together momentarily. On the up-stroke the lug 26 presses spring 1 away from the rest and they make no contact. On hanging up, lug 24 presses the ground spring, 7, to the right and lets lever, 22, slip in to

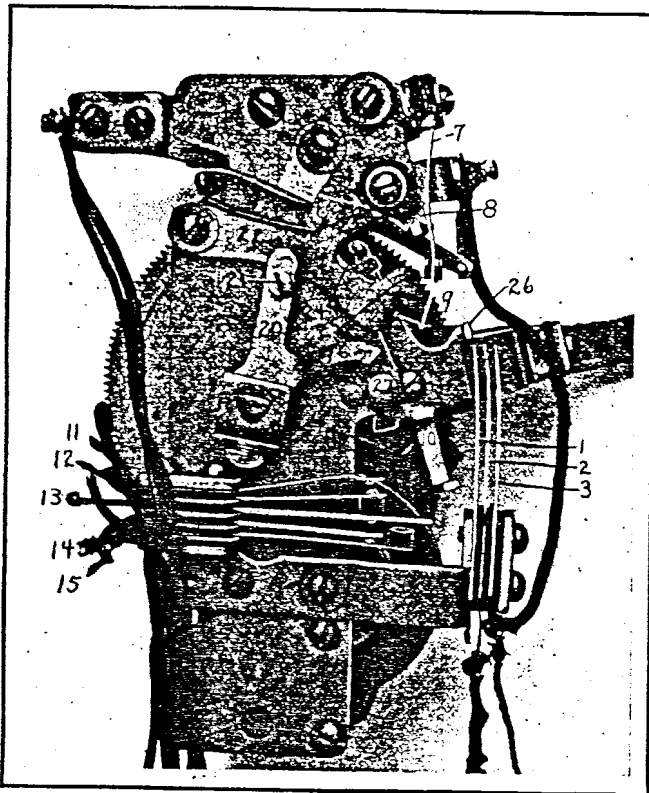


Fig. 69—Chicago Substation Sender, Showing Contacts as They Appear When First Digit is Pulled.

hold it there. Thus the apparatus is restored to the condition of Fig. 67.

Fig. 70 shows the substation wiring. The rotary line is the common return for the ringing and talking circuits in the instrument, both bell and receiver being permanently wired to it. With the receiver on the hook only the bell is across the line. With the hook up, the receiver and the secondary of the induction coil are put across the line in place of the bell. The local battery circuit for the transmitter is also closed by springs 14 and 15. During the rotation of the dial, lever 16 is lifted off spring 11, separating the vertical and rotary lines, while springs 4 and 6 are grounded according to the code. This code is simple and is the same for all digits, consisting of a series of impulses on the vertical line, followed by one impulse on the rotary line. Thus the necessity for the old reverser and star wheel was done away with. To ring, spring 18 of the ringing button is pressed, grounding the vertical line alone.

The first selector is shown in Fig. 71. At the left are the vertical and rotary lines coming from the substation. Each passes through a line relay, 30 ohms, a side-switch lever, and a 500-ohm retardation coil to negative battery, the positive terminal of which is grounded. The voltage was not far from 55 volts. The vertical relay controls the vertical magnet, or if the private magnet be energized, the release magnet. The rotary relay controls the meter magnet directly. The meter magnet acts on a mechanical message register, or counter, which is attached to the framework of the selector. The meter magnet carries a contact which is able to ground the private magnet, and thus operate it. Hence the rotary relay really controls both magnets simultaneously. The rotary magnet has a finger which touches the armature of the private magnet, so that the former will actuate the latter. The interruptions for the ro-

tary magnet come from a set of springs operated by a motor which is kept running continuously.

The various members of the side-switch are numbered 1, 2, 3, 4, and 5, and are shown in their initial positions. In the machine they are built together mechanically, all moving together, and are controlled by the end of a lever, *S*, in the springs of the private magnet. A spring tends to move the side-switch lever, *S*, in the direction of the arrow, which would move all the members to the second and third positions. If the private magnet be energized, *S* slips past a tooth on the lower spring, but is caught by the tooth on the upper arm before it has moved far enough to affect the switch contacts. But when the private magnet is released, *S* slips to the left to the second tooth on the lower spring, thereby bringing each member to its second position.

This action of the auxiliary switching device, by means of which the act of releasing instead of pulling up the private magnet is made to operate the side-switch should be kept in mind, as it appears in all subsequent switches of the Strowger line, and need not be described again.

Fig. 72 presents the second selector with some new features. There are two vertical and two rotary line relays, distinguished by their resistances, 30 and 500 ohms respectively. The 30 ohm relays are mounted together mechanically, each having a single spring. It requires the operation of both at the same time to bring them together, either relay alone not moving its spring far enough to touch the other. This is utilized to operate the release magnet.

To the 500-ohm line relays is given the work of directing the selecting mechanism. The 500-ohm vertical relay controls the vertical magnet. The 500-ohm rotary relay controls the private magnet. The circuit controlled by each relay passes through the back contact of the other relay, so that if both are pulled up at the same time, nothing will be affected.

The connector is shown in Fig. 73. Again the 30-ohm vertical and rotary relays do not perform their usual functions, the work being delegated to other relays, 500 ohms each, in series with them. They are called the vertical retard and rotary retard respectively. The vertical line has permanent connection to battery, but the rotary line, after passing through the rotary relay and rotary retard, goes through a contact on the busy relay to get battery. The vertical retard breaks the vertical line and grounds the vertical and rotary magnets. The rotary retard breaks the rotary line and grounds the side-switch magnet. The latter is exactly like the private magnet of previous switches, except that it is not in the feeder circuit to the private wiper, that function being here taken by the busy relay.

Side-switch lever No. 4 acts as a distributor of battery to the

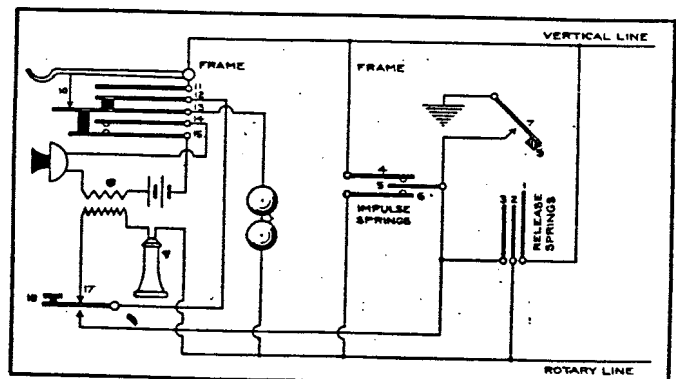


Fig. 70—Wiring of Automatic Substation Sets Installed at Chicago.

vertical and rotary magnets, and the ringing magnet. In addition to operating the side-switch, the side-switch magnet cuts battery off side-switch 4 when desired. The busy relay and busy release relay occupy a similar mechanical relation to that of the vertical and rotary relays in the second selector. If the

busy release relay is pulled up, spring *A* is moved over a little more than half way toward spring *B*. The busy relay must be energized at the same time to bring them together.

As explained before, the code of signals sent in by the substation sender consists of a series of impulses on the vertical line, followed by one on the rotary line. This is repeated for each digit. The first series is taken care of by the first selector, Fig. 71. The vertical relay grounds the vertical magnet, stepping the wiper shaft up to the desired level. The single impulse on the rotary line pulls up the rotary relay, which operates both meter magnet and private magnet. The latter brings the side-switch levers into their second or middle position. Levers 1 and 2 do not effect any change. Lever 3 connects the private wiper through the private magnet to battery, to act as feeler for non-busy trunk. Lever 4 cuts off the vertical magnet, while No. 5 connects the interrupter (ground) to the rotary magnet.

The first motion of the rotary magnet, while rotating the wipers into contact with the first trunk, pushes the armature of the private magnet against its polepiece. If the first trunk is busy, there will be a ground on its private contact, and the private magnet will be held up by the resulting current. But on striking the first non-busy trunk the private wiper finds no ground, the private magnet releases, snapping the side switch into its third position and cutting off current from the rotary magnet. Levers 1 and 2 connect the rotary and vertical lines through to the trunk lines leading to the second selector, while No. 3 disconnects the private magnet from the private wiper,

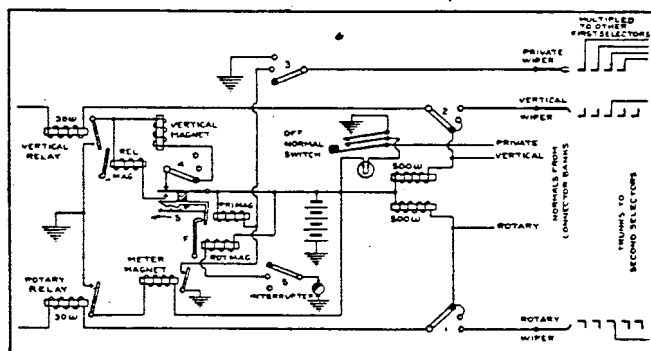


Fig. 71—Wiring of First Selector In Chicago Installation.

putting the latter to ground as a protection from other first selectors who might try to get in on the same trunk. The first upward motion of the wiper shaft closes the off normal switch, putting ground on the private normal so that incoming calls to this calling subscriber will get a busy signal.

The second series of impulses affects the second selector, Fig. 72. As before stated, the 30-ohm vertical and rotary relays have nothing to do with selection, being used only for release, and will be neglected while working through our call. On receiving the series of impulses over the vertical line, the 500-ohm vertical relay grounds the vertical magnet, stepping the wiper shaft up to the proper level. The single impulse on the rotary pulls up the 500-ohm rotary relay, causing the private magnet to step the side-switch over to the second position. At levers 1 and 2 no change is made. At 3 the private wiper is connected to the private magnet to serve as a feeler, as in the first selector. Lever 4 disconnects the vertical magnet, while 5 connects the interrupter to the rotary magnet. The test and selection of a non-busy trunk is identical with that of the first selector.

The connector, Fig. 73, takes the last two digits, tens and units. The vertical relay operates the busy release relay, but if its mate, the busy relay, is not energized, nothing will happen, as spring *A* can not touch *B*. While stepping up and around, the vertical relay can not affect the ringing magnet, though connected to it, since its circuit is open at the side-

switch lever 4. On receiving the series of vertical impulses for the tens digit, the vertical retard grounds the vertical magnet a certain number of times, stepping the wiper shaft up. The following ground on the rotary energizes the rotary retard, causing the side-switch magnet to move the side-switch over to

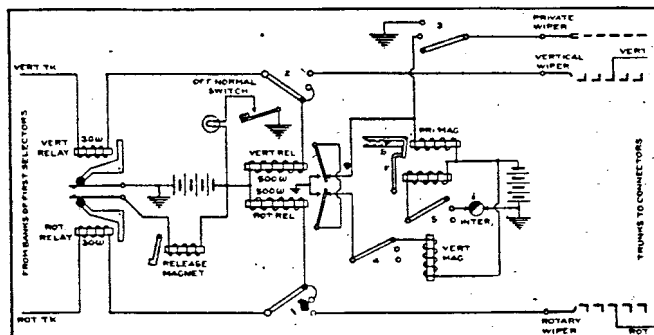


Fig. 72—Chicago Second Selector Wiring, Showing Two Relays For Each Side of Line.

the second position. At lever 1 this action connects the busy tone to the rotary line, but as the subscriber is not listening it has no practical effect. Lever 2 causes no change. Lever 3 connects the private wiper through the busy relay to battery, so that if the called line proves to be busy it will be safeguarded. Lever 4 shifts battery from the vertical to the rotary magnet.

The series of impulses for the units will operate the vertical retard, grounding the rotary magnet and rotating to the called line. The last impulse on the rotary line pulls up the rotary retard, causing the side-switch magnet to step the side-switch over to its last position. At levers 2 and 1 this action connects the vertical and rotary lines to the corresponding wipers which are resting on the called line. At 2 the private wiper is switched from the busy relay and connected to ground, to make the line busy against others. At 4 the battery is switched from the rotary to the ringing magnet. The pushing of the ringing button at the substation grounds the vertical line, pulling up both vertical relay and vertical retard. The latter does nothing. The vertical relay now grounds the ringing magnet, which projects alternating current out on the called line, cutting off the line behind it as is done in the manual ringing key.

If the called line is busy, the effect is as follows: Suppose we are at that point in selecting where the wipers, under the influence of the units vertical impulses, are rotating to find the called line. The side-switch is in the second or middle position, so that the battery is connected through the busy relay to the private wiper. The called line, being busy, will have

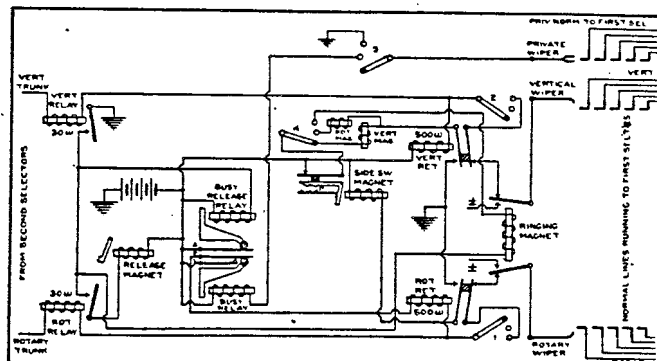


Fig. 73—Chicago Connector, Equipped with Vertical and Rotary Retard Relays.

ground on its private contact. When we arrive there our busy relay will be pulled up, cutting battery off the rotary line. The series of vertical impulses are followed by one on the rotary, but as the battery is cut off the latter this last impulse will not occur, as there is no complete circuit. Thus the side-switch is left in its middle position.

The calling subscriber, ignorant of this fact, pushes the ringing button, grounding the vertical line. The vertical relay is pulled up, operating the busy release relay. As the busy relay is energized by the ground on the private wiper, spring *A* will touch spring *B*, putting battery back on the rotary line; but this will not move anything. The vertical retard pulling up operates the rotary magnet, moving the wipers away from the busy line onto the next higher number. Then, while listening for the called subscriber to answer, the calling subscriber hears the busy tone through the middle contact of side-switch 1.

If the line to which the wipers have been rotated is also busy, the busy relay will still be energized, making the rotary line dead. This would prevent the release, were it not for the busy release relay. When the unsuccessful calling subscriber grounds both lines to release, the vertical relay pulls the busy release relay up, restoring battery to the rotary line. Since the latter is grounded at this instant at the substation, the rotary relay will pull up, operating the release magnet, which allows the wiper shaft to return to its initial position. The side-switch is also automatically reset by the release magnet.

The normal release is from a non-busy line with the side switch in the third position. Here it is only necessary for the vertical and rotary relays to pull up, the former to supply ground, the latter to connect that ground to the release magnet. At the same time the vertical retard pulls up and would ring the called line were it not that the rotary retard pulls up the side-switch magnet, cutting off battery from lever 4. In the first and second selectors the 30 ohm vertical and rotary relays alone are left in the line, and through them the release must take place. The mechanically mutual action of the 30 ohm vertical and rotary relays of the second selector has already been described. In the first selector, Fig. 71, the rotary relay operates the private magnet. The latter switches battery from the vertical magnet to the release magnet. As the 30 ohm vertical relay is also energized, the release magnet finds ground through its contact.

To provide for counting messages, in the Chicago system, a meter was attached to each first selector. It is shown in detail in Figs. 74, 75 and 76. Fig. 74 is a front view, showing the mechanism in its normal position. Fig. 75, shows the left side, normal, while Fig. 76 shows the left side while a call is being put through. The counter or message register proper consists of the ordinary collection of wheels and cylinders, so arranged that ten revolutions of one are required to cause one revolution of the next higher. The mechanism of this forms no part of the message register patent, taken out by the inventor, John Erickson, and has nothing to do with the principles described below.

On the end of the register proper is mounted a toothed wheel, 5. On the side of the wheel are ten pins, 6, each pin representing a completed call. The meter magnet, 7, has an armature, 9, to which is attached a lever, 10, carrying a pawl, 11. The pawl is normally out of contact with the edge of wheel 5, but is adapted to move it one notch when the magnet is energized once. A detent, 12, is adapted to engage the teeth of wheel 5, and is held in spring-like contact by spring 15. But when the first selector is in the released or initial position, the torsion head, 13, of the wiper shaft, 14, bears down on the lever and raises 12 from the wheel 5. A detent, 16, is mounted on a shaft, 17, with a spring, 18, arranged to cause the detent 16 to press against the pins, 6, of the wheel 5.

In Fig. 75 the detent is normal, pressing against the pin at its left. This tends to turn the wheel backward, in the direction opposite to the arrow, but is prevented from doing so by the pin just above the detent pressing down on the end of 16. In Fig. 76 the wheel is turned forward almost far enough for detent 16 to fall under the pin. It lacks one notch of so doing. In this position there is a pressure exerted by the detent against the pin tending to force it to the left and rotate the wheel backward. If magnet 7 be released and detent 12 be lifted, detent 16 will push to the left and turn the wheel backward to the position shown in Fig. 75.

By referring to Fig. 71 ~~it will be seen~~ it will be seen

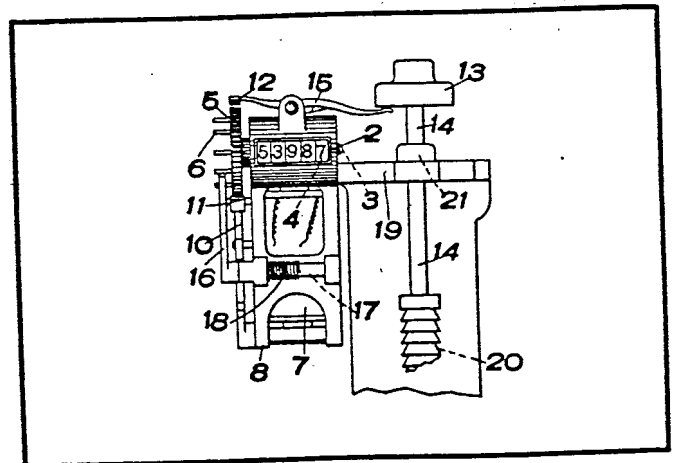


Fig. 74—Front View of Meter, Normal Position, as Installed in Chicago Automatic System.

that the meter magnet is firmly linked with the rotary line, where all impulses over that line will energize it. In the completed call in the 10,000 system, there are five such impulses, one for each digit and one for the release. Hence there are five teeth on wheel 5, Fig. 75, for every pin, 6

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This makes 50 teeth in the whole wheel. By referring to the connector, Fig. 73, it will be remembered that when a busy line is selected the busy relay cuts off battery from the rotary line. This makes one rotary impulse fail, leaving only four. Upon this difference the message register is based. In the completed call, that is, if the called

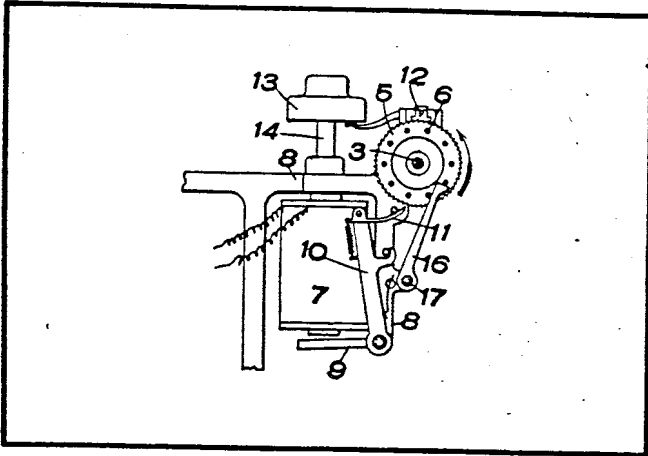


Fig. 75—Side View of Chicago Meter, in Normal Position.

line is not busy, the five rotary impulses move the wheel 5, Fig. 75, five notches, so that detent 16 falls under the passing pin, 6, locking the counter with the one added call. But if the called line is busy, the meter magnet, 7, gets only four impulses in all. During the last of the four, the release impulse, it assumes the position of Fig. 76. Now, when this last impulse ceases, the falling wiper shaft, 14, presses its torsion head, 13, against the lever of detent 12, disengaging it from the teeth of wheel 5. The pressure of detent 16 to the left now rotates the wheel backward to the number previously recorded.

In manual practice it has been customary not to charge for calls if the called station does not answer. In other words, the telephone company undertakes to give the subscriber connection with *somebody* at the desired number. The automatic could not go as far as that at that time, but as shown above no charge was made for calls which found the called line busy.

Fig. 77 shows the relations existing between first selectors and connectors by means of which privacy is secured. At the left are shown in skeleton some parts of a first selector. This first selector is one of a group, and the banks of all of them are multiplied together. The wires for the private bank end in the group, merely connecting the banks. The vertical and rotary trunks lead to other groups, where they terminate in second selectors. When any trunk is occupied, the corresponding private wire is grounded by the side-switch lever 3 being in the third position, and the private wiper resting on that private wire contact. Thus any other subscriber in the group will find a ground on the private contact multiplied to it and be prevented from interfering. At the same time the off-normal switch grounds the private normal, which comes from the group of connectors at the right. This group has the duty of taking care of all incoming calls to the subscribers whose first selectors are at the left. From the particular first selector which is shown the vertical and rotary normals run to the connectors and are multiplied to corresponding points on all the banks in that group. The private normal is also multiplied to corresponding contacts in each connector bank. If the line at the left is busy by having made a call, this private normal gets its ground from

the off-normal switch. If it is busy by having been called through a connector, at the right, its ground will come from the private wiper of that connector through which the call came, since the side switch lever 3 will be slipped over to the grounded point.

Fig. 77 also shows how the called subscriber may temporarily

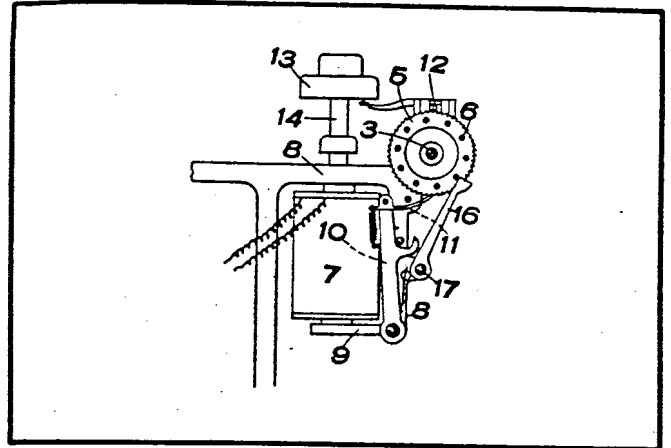


Fig. 76—Side View of Chicago Meter While a Call is Being Made.

leave the calling subscriber and come back again. Suppose someone has called the subscriber whose first selector is there shown. The connector at the right has made the necessary movement, so that connection is secured through side-switch levers 1 and 2 of the first selector. While the calling subscriber at the right waits, the called subscriber at the left can move his dial, operating the first selector as if not connected, and make any call desired. Levers 1 and 2 merely cut off the calling subscriber, leaving him there with battery through the retard coils so that he can release if he gets tired of waiting. When the first selector releases, the levers 1 and 2 will re-connect to the waiting subscriber if he is still there. This feature was considered quite valuable. It also enabled one to get away from a person who became annoying in any manner over the telephone.

The Illinois Tunnel Company desired to have special arrangements made for a plurality of lines to some of its offices for company's business. It was desired that calls to these numbers should be free and also select the first non-busy line. To meet the demand for this class of service a special connector was devised. It is known as the automatic selecting connector, Fig. 78. A third selector built like a second selector could have been used for this purpose were it not for the busy test

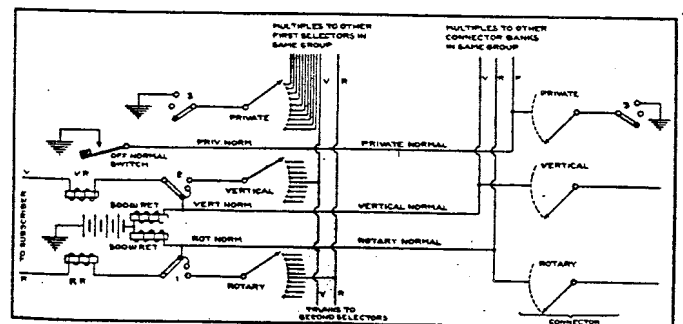


Fig. 77—Relations Between Chicago First Selectors and Connectors Which Insure Privacy.

and ringing. Comparing this special connector with the regular connector, Fig. 73, the following changes will be noted: The rotary magnet has been taken from the middle point of side switch 4, tied permanently to battery, and provided with its own side switch lever, 5. The middle point of this is grounded. The rotary magnet has its own interrupter spring, breaking its

own circuit much like a common door bell. Also the finger, *F*, which reached over to the side-switch magnet armature, is replaced, as in a selector. The wire which ran from the middle point of side-switch lever 3 to the busy relay is cut off from the latter and tapped to the side-switch magnet.

To call any of the company's telephones thus equipped required only three digits, so that there were only four rotary impulses in the completed call and no record on the meter. This leaves only one digit to affect the connector. The series of vertical impulses lift the wiper shaft to the desired level. The final impulse on the rotary pulls up the rotary 500 ohm retard, energizing and releasing the side-switch magnet. As the side switch snaps into its second position, lever 5 starts the rotary magnet to vibrating. The first pull of the latter presses the finger, *F*, against the armature of the side-switch magnet, getting the side switch ready to snap into the third position when a non-grounded private point is reached. This stops the rotary magnet as in a selector.

24. Summary of events thru 1902

It will be profitable at this point to examine some of the details which have been developed by the experience of the years up to 1902. We have seen that the earliest inventors tried to use switches moved by electromagnets, and that these motor magnets, as they may fitly be called, were placed directly in the line. This method proved a flat failure. Even the perfecting of the magnet could not make it a success.

To escape the difficulty two courses seemed open. The first was to drive the switch by an independent motor and control its movements by magnets, the latter having very light duty. The second was to reduce the switch friction, operate it by motor magnets on local circuits, and control these circuits by relays in the line. The Strowger development, which is just now occupying our attention, follows this second line of attack. Other systems which we shall take up later operate on the motor-driven plan.

To distinguish the two principal classes of electromagnets from each other the words "relay" and "magnet" are used. A relay is an electromagnet which has for its only duty the controlling of other circuits, as the vertical relay, which controls the vertical magnet, or the ringing relay, which switches on the ringing current. A magnet is one which moves apparatus directly, as the vertical magnet, which by its magnetic pull lifts the wiper shaft, or the private magnet, which allows the side-switch to slip from notch to notch, though the motive power comes from a spring. The magnets are usually much lower in resistance than the relays, and require considerable current. Those magnets having only 25 ohms resistance, and receiving full battery voltage would take two amperes if the current were allowed to flow steadily. But it is not likely that such current ever flows, since these low resistance magnets are operated by interrupted current, which probably has not time to arrive at full value between impulses.

The magnet must be quick-acting and powerful; the former to enable it to follow the impulses as fast as they come, the latter so that it can move the apparatus promptly and certainly. To meet this need a form with a good magnetic circuit was used, one in which the air-gap is as small as possible

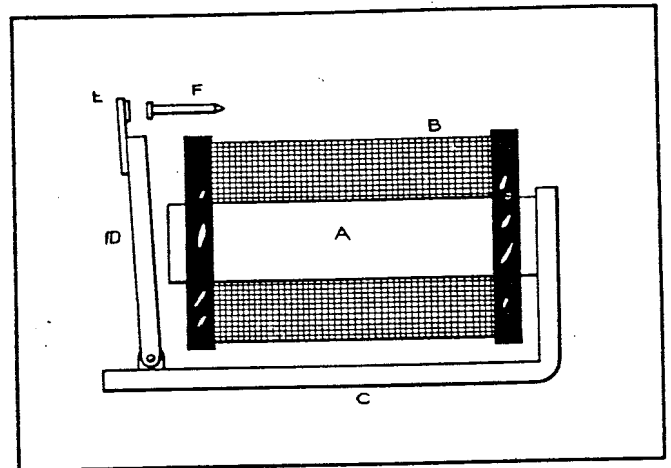


Fig. 79. Form of Old Style Relay.

and yet allow considerable motion. The knife edge armature, such as is used in the Western Electric line relay at the present time (1908) was not a success, as there was too little iron at the knife edge. The successful magnet is U-shaped and has

two coils, one on each limb. This gives a solid magnetic circuit in iron, except at the two armature air-gaps. The play in the pivots is made as small as possible, for a little lost motion is fatal to high speed action. In addition, the restoring spring is applied in such a way that in its normal position it will press the armature against the side of the pivot bearing, against which it will be pressed by the energizing of the coils.

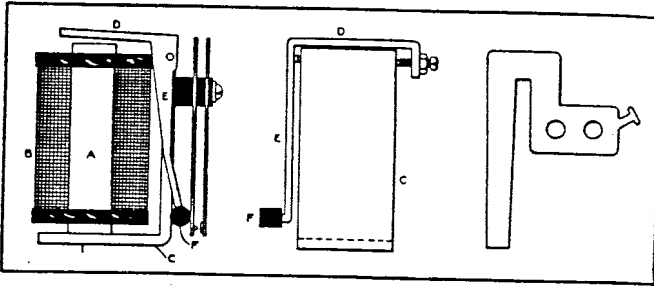


Fig. 80. Form of More Recently Developed Relay.

The breaking of the heavy current required by this magnet produced a destructive arc at the contacts of the controlling relay. This was at first reduced by a 150 ohm non-inductive shunt placed around the winding. This has given way to a copper shield or tube on the core. Of course the use of platinum contacts was found to be imperative.

An entirely new form of relay was also necessary. The first commercial relays were probably those used in telegraph work. They must be sensitive, quick acting, and capable of ready adjustment from day to day. There is no reasonable limit to their cost, as they are used in comparatively small numbers and form a small part of the total cost of a telegraph line. When the common battery telephone system began to come into use, it also demanded relays, but of a different type, though for a time the telegraph relay was pressed into service in many places. They need not be quick-acting. They should be adjustable, but rather of the permanently adjustable type, for line conditions must not affect them as much as they do the telegraph. But above all things the common battery telephone relays must be as cheap as is consistent with good apparatus, since their number runs up into thousands in a single office. For this purpose the modern telephone relay of various types has been developed.

But the automatic system calls for still another kind of relay, which is in some ways a cross between the telegraph and the telephone as to requirements. It must be quick-acting and accurate,—if possible more so than the telegraph relay. Its requirements as to adjustment are the same as for the ordinary telephone relay. But there is a greater necessity for limiting its cost, since more are used per line than in the manual.

The early inventors had not grasped the idea of speed. Their switches were operated by push buttons at the substation. The user would probably push the buttons not faster than four impulses per second, a rate which was easy for even a poorly designed relay to follow. It soon became apparent that if the automatic were to win, it must act with greater speed. The relays were improved, the automatic sender (dial) introduced, and the speed of impulses increased to from 10 to 20 per second.

The general form of one of the older relays is shown in Fig. 79. The core, *A*, carries the wire, *B*. A soft iron piece *C* forms the second pole of the magnet. The armature, *D*,

is pivoted on the end of *C*. The solid piece, *E*, is fixed to the armature and carries the platinum rivet. When energized the armature pulls up toward the pole of the core *A* until stopped by *E* striking *F*, the stationary contact. There was

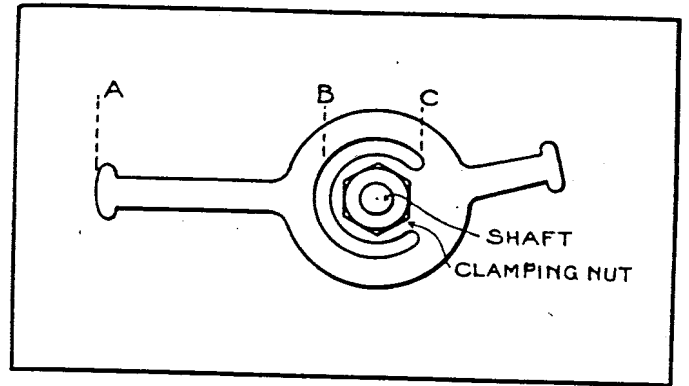


Fig. 81. Detail of Wiper.

no elasticity in the contact, and no sliding action between the platinum rivets.

The present relay, whose form was established about 1901 or 1902, is shown in Fig. 80. At the left is a front view, in the middle its right side without springs, and at the right a single spring. *A* is the core, on which is placed the winding *B*. The return limb of the magnetic circuit is *C*, which carries the pivots for the armature *D*. Attached to the armature is a long arm, *E*, carrying an insulating plunger, *F*. The latter moves the springs, which are mounted on the return limb, *C*. Attention should be called to the shape of the spring, at the right, Fig. 80. Though limited vertically so that a short, stiff spring would seem to be the only possibility, yet by its unverted U shape it has the effect and elasticity of a much longer spring.

It will be seen that the air-gap between the armature and pole is small while relatively large motion of the plunger, *F*, is obtained. The ratio of plunger to armature motion is about $2 \frac{1}{3}$ to 1. Also there is a very good path for magnetic lines of force.

Working at high speed brought out the fact that the presence of a few short-circuited turns in the winding very materially reduces the rapidity with which it will follow signals. These short-circuited turns prevent the armature from falling back promptly and thus tend to run the impulses together. So it was necessary to use the greatest care in winding, testing, and

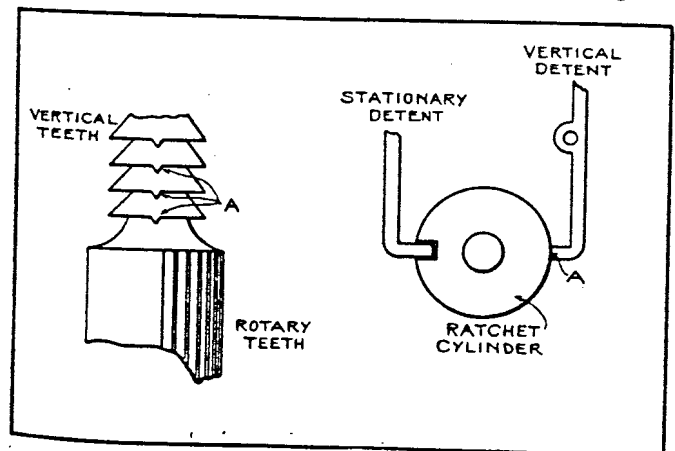


Fig. 82. Details of Ratchet Cylinder.

handling relays and magnets for automatic work. These requirements are much more severe than for manual work.

The circuits of the automatic exchange were originally fused the same as in other telephone plants. But the high voltage of the automatic soon made it necessary to subdivide the pro-

tection into smaller units. The heat coil replaced the fuse at the switches, the automatic people designing and making a type of their own. At first both battery leads, ground battery and main battery, were protected, but by the time Chicago was installed the heat coils in the ground lead were omitted in accordance with manual practice. Each switch was provided with two heat coils, called "external main" and "local main" respectively. The former supplied battery to the vertical and rotary lines through the line relays, and was so named because its current went out of the office. The local main heat coil supplied all the rest of the apparatus in the switch, which was on locally completed circuits.

The individual interrupter for operating the rotary magnet came into use about this time. It consisted essentially in providing the rotary magnet with a spring contact which would break when the armature was attracted. This contact was wired in series with the winding. When connected to battery the resulting vibratory motion was not unlike that of an ordinary battery door bell. The conditions were more severe, as the contact had to remain closed until the magnet had completed its forward thrust and rotated the wipers onto

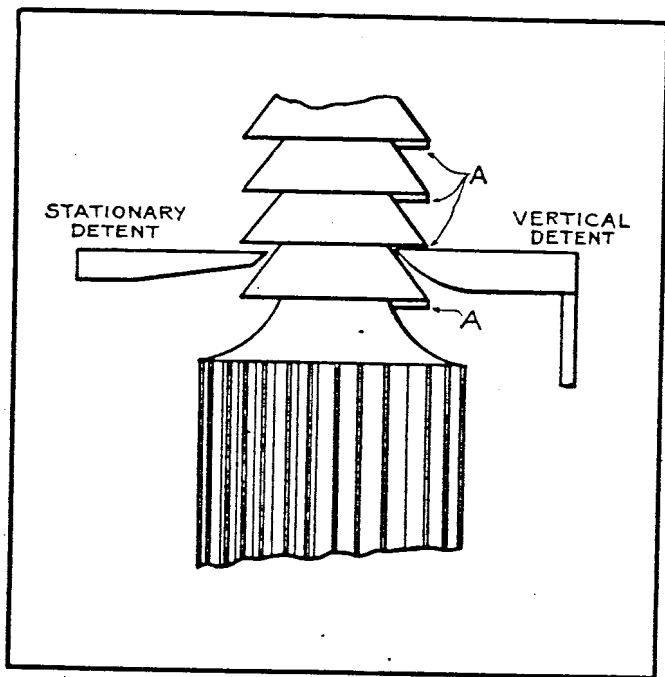


Fig. 83. Ratchet Cylinder, and Relations of Detents.

their next contact. It must then remain open until the armature had been pulled by its spring back far enough for its pawl to catch the next tooth of the ratchet cylinder. There was not the inertia of a long lever and hammer, as in the door bell, to lengthen the stroke. The moving parts were light compared to the forces moving them, and the forward stroke was against a variable resistance. The result was finally obtained partly by the design of the springs and partly by their careful adjustment.

For the proper working of the switch it is essential that all the movements shall be performed in a certain order. This order is fixed by the side-switch—which is the key to the average machine. To prevent the side-switch from being accidentally moved from its initial position before the right time is the function of an attachment of the release magnet. The vertical and rotary detents are in one piece, and pivoted. Attached to a lever on these detents is a rod running to the side-switch. When the release magnet is energized, it pulls up and allows a spring loop on its armature to drop over a lug on the lever of the vertical and rotary detent piece. When the release magnet falls back, it rotates the detent piece, lifting the detents from the ratchet cylinder, so that the wiper shaft

can return to its normal position. At the same time that the detent piece rotates, it pushes the rod running to the side-switch, thereby resetting the latter. During idleness the release magnet retains its hold on the detent piece, preventing the detents or side-switch from moving.

The armature lever of the vertical magnet lies just under the spring loop of the release magnet. On its first upward motion this lever lifts the spring loop off the lug on the detent piece. The detents come at once into action, but the side-switch is controlled by the private magnet as has been described.

To keep the side-switch from going into its third position too soon, there is a large cam or blade on the shaft just below the ratchet cylinder. A lug on the side-switch lever projects toward this long cam. After the wiper shaft has been lifted, the private magnet will slip the side switch into its second position. Here the lug on the side-switch lever will rest against the long cam on the shaft, and the side switch cannot move farther until the shaft has rotated at least one notch.

While the shaft is in its normal position, no rotary motion is possible. This is secured by having attached to the top of the wiper shaft a finger which drops down behind a stationary peg. This peg is just high enough to hold the finger from moving, yet the latter will clear it when lifted one notch.

The difficulty of securing sufficiently flexible wipers in the small space available was solved as shown in Fig. 81. The effective length of the ordinary spring would be from *A* to *B*, but by this device it is lengthened to the distance *A-C*.

By having all parts made to interchangeable sizes the switch was designed to be easily removed from the bank. The latter was wired into place and expected to stay there, for little or no trouble was experienced with it or its wiring. But the switch proper could be removed and a new one substituted while the old one was repaired, all without disturbing the bank. To do this, and be sure that under the conditions of average use the wipers would line up and move freely over all of the 300 contacts is no small feat.

At the left of the wiper shaft, opposite the vertical portion of the ratchet cylinder, is a stationary detent, fastened rigidly to the framework. Its end projects into a channel cut in the teeth acted on by the vertical magnet. It is the duty of this detent to carry the weight of the shaft while rotating, and prevent any downward motion from injuring the wipers. During the upward motion the weight of the shaft has been held by the vertical detent, which is in one piece with the rotary detent. When the rotary magnet makes its first move, the weight of the shaft must be transferred from the vertical detent to the fixed detent above mentioned. To do this with the least possible friction is the object of the following device.

Fig. 82, at the left, shows a portion of the vertical ratchet cylinder, the upper end of the rotary portion showing below. On each of the teeth will be seen a small downward projection, *A*. During the upward movement these projections are in line with the vertical detent, and at every step one of them rests on it. At the right in Fig. 82 will be seen the relation between the detents. These little projections, *A*, hold the shaft a little higher than necessary, so that the bottom of a tooth is a little above the top of the stationary detent (See Fig. 83). Therefore, when the rotary motion begins the shaft will be let down easily onto the stationary detent instead of being forced on.

Though the installations which have been described were successful from a switching point of view, they still possessed the drawback of being series systems. That is, there was a 30 ohm relay in each side of the line in each switch used in the completed connection. In the 10,000 system employing first selectors, second selectors, and connectors, this meant six such coils. The copper shield on the core doubtless reduced the inductance considerably, yet the effect on transmission of speech was very appreciable. A system with no series relays was the next step. It was worked out during the winter of 1902-3, and installed at Dayton, Ohio, being the first bridging automatic system.

Briefly the change consisted in winding the line relays of each switch to 500 ohms and arranging them so that the pair is permanently bridged across the talking circuit. In this relation they are not in the path of the talking current, but form highly inductive leaks which allow only a very small current to be lost.

The substation was the same in wiring as that used at Chicago. The first selector is shown in Fig. 84. The vertical and rotary relays are connected to battery through the back contacts of the bridge cut-off relay. The vertical relay has for its duty the grounding of a certain wire, which the private magnet may switch from the vertical magnet to the release magnet. The rotary relay controls the private magnet. The machine interrupter was used. At rest, the vertical and rotary lines are connected through side-switch levers 2 and 1 to the normal lines, over which calls are received from other subscribers. These normal lines are cut off by the side-switch, which also cuts the talking circuit straight through to the wipers. The private normal is tapped onto the private wiper, which is wired as usual to the lever No. 3 of the side-switch. The first contact is wired to the bridge cut-off relay, but during operation the private wiper is switched to the private magnet, to act as a feeler, and finally to ground.

The second selector is shown in Fig. 85. It differs from the first selector in the following particulars: The vertical and rotary relays are permanently connected to battery, there being no need of a cut-off relay. There are no normal lines.

The connector is shown in Fig. 86, and has a number of interesting points. The vertical and rotary lines each have a 2 m. f. condenser inserted. While preserving the continuity

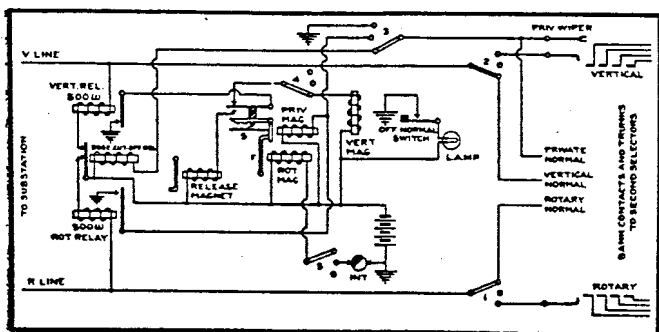


Fig. 84. First Selector Circuit with Bridged Line Relays.

of the line for talking purposes, for signaling this divides the line into two parts, the left hand end for the calling, and the right for the called subscriber. The vertical and rotary relays are controlled by the former. The back release relay and the back signal relay are similarly controlled by the called subscriber.

The vertical relay has the duty of grounding and thus operating any one of four magnets. If the private magnet be normal, the vertical relay contact reaches the lever of side-switch 4, and can be switched from the vertical magnet to the rotary magnet and the ringer relay in succession. If the private magnet, under the control of the rotary relay, be pulled up,

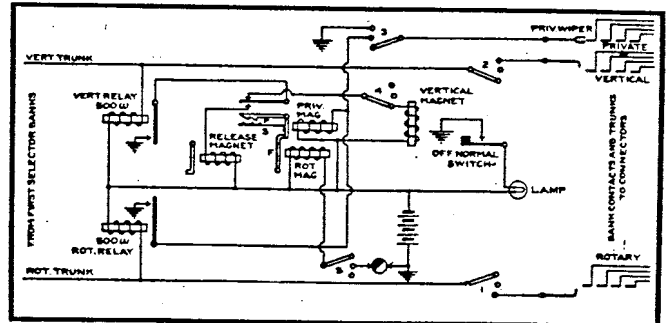


Fig. 85. Second Selector of Bridging System, Installed at Dayton.

the vertical relay will ground the release magnet through another contact on the rotary relay.

The vertical line and relay are seen to be the impulse transmitting members, for over them come all the signals that determine the number which shall be selected. The rotary side of the line is the directing member, for the single impulse on it changes the activities of the vertical from time to time, causing them to be applied where they will advance the call. In the 10,000 system there are five sets of impulses on the line in selecting and ringing a station, the thousands, hundreds, tens, units, and the ringing. The series of impulses corresponding to the thousands is applied to the first selector, lifting its wipers up to the desired level, after which the trunk to the thousand group is selected automatically. The hundreds impulses are expended on similar activities in the second selector. The tens impulses lift the wipers of the connector to the proper level, while the units cause the same wipers to rotate to the called line. The final vertical impulse rings the called station.

It is the function of the rotary line and relays to shift the connections in such a way as to make possible this varied work of the vertical. This accounts for the fact that every digit in the call number requires a series of vertical impulses, followed by one on the rotary, and is one of the cardinal points in the Strowger system. It should be thoroughly mastered by the beginner.

The rotary relay of the connector has an added contact, which connects the release magnet to the center point of side-switch No. 3. This allows the release magnet to be connected to the private wiper to detect the condition of the called line, and if that is busy it will release the connector.

The ringer relay contacts are cut into the line back of the side-switch levers 1 and 2. The back release relay is connected from battery to the vertical line on the called side of the condenser, and occupies a similar position to the vertical relay. It controls a tap to the release magnet. The back signal relay similarly carries battery to the rotary line. It grounds a connection from a contact of the back release relay, so that if both be energized at once the connector will be released. It also grounds the rotary line to the calling end through 500 ohms. Owing to a transposition of the wires between the side-switch and the wipers, the back signal relay is connected to the vertical line to the called station, and the

back release relay to the rotary line. If the called subscriber wishes to get away from an obnoxious person, he can do so by moving his dial once and hanging up. The turning of the dial is necessary to let the substation ground spring down on the local ground wire, so that when the hook descends it will

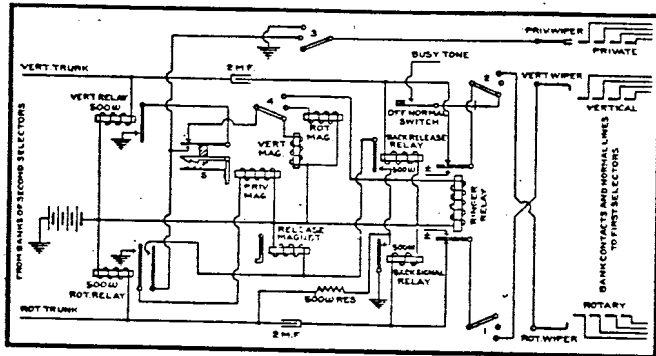


Fig. 86. The Dayton Type Connector.

have a real ground to contact the lines. But the primary purpose of the back signal relay is given below.

If an automatic subscriber desires a toll connection, he calls the toll operator by the dial, the "O" hole being reserved for this purpose. This trunks his call directly to the toll board. After taking his call, the operator tells the subscriber to hang up and that he will be called when the connection is ready. When the distant party is secured and the toll line connected, the toll operator calls the subscriber with a dial. Thus the toll connection reaches the subscriber through the connector switch. Under direction of the operator he turns his dial once and begins the conversation. If for any cause he wishes to signal the toll operator he can do so by pushing the ringing button. This pulls up the back signal relay, Fig. 86, placing a 500 ohm ground on the rotary line.

In Fig. 87 is given the scheme of the toll connection through all the switches. At the left is the toll line, connected through a repeating coil in the cord circuit to the first selector, second selector, and connector and thence to the subscriber at the right. When he presses the ringing button the back signal relay pulls up, placing a 500 ohm ground on the rotary line. This tends to pull up all the rotary relays in a parallel. Owing to the 500 ohms resistance they may or may not act, but if they should, no harm will result. The other path is through winding A of the relay in the cord circuit to the vertical line and through all the vertical relays in parallel to battery. Relay AB pulls up, but the vertical relays in parallel to battery. due to AB and the 500 ohms preventing. When the relay contact closes winding B locks it there, at the same time the clearing out signal is energized. When the operator listens in, the extra contact on her listening key unlocks the relay and restores the signal.

Fig. 87 also shows diagrammatically the conditions existing during a conversation. There are three 1,000 ohm bridges across the circuit. If we imagine the toll board at the left to be replaced by a substation set, we shall see that in releasing, when the vertical and rotary lines are simultaneously grounded, all six relays will be pulled up at once. The release action in each switch is essentially the same, the vertical relay furnishing ground while the rotary relay, through the private magnet, switches that ground onto the release magnet.

If the called line on any connection is busy, the action is as follows: normally the vertical line, Fig. 86, is connected through side-switch 2 to the off-normal switch, which in this case is wired to the busy tone. Being open, by the downward weight of the shaft, no busy tone gets onto the line. The tens impulses come in on the vertical, and through the vertical relay operate the vertical magnet, stepping the wipers up. The following ground on the rotary line steps the side-switch

over to the second, or middle position. At 1 and 2 this does nothing, except to disconnect the busy tone, which has been connected by the off-normal switch. At 3 it connects the private wiper to a wire which goes through an open contact on the rotary relay to the release magnet. At 4 it switches the contact wire of the vertical relay from vertical magnet to rotary magnet.

The units impulses on the vertical wire now operate the rotary magnet, rotating the wipers to the called line. If it is busy, its private contact will be grounded. Now the succeeding impulse on the rotary will pull up the private magnet in an endeavor to shift the side-switch to the third position. But at the same time the second contact on the rotary relay is closed, connecting the release magnet to the private wiper. The release magnet instantly pulls up and releases the switch, the wipers returning to their normal position. The side-switch levers are also returned to the position shown in the figure.

The subscriber, not knowing what has happened, presses his ringing button, which grounds the vertical line. Since side-switch 4 is again in its initial position, this operates the vertical magnet, stepping the wiper shaft up one or more notches. This closes the off-normal switch, which connects the busy tone to the vertical line so that it will be heard by the calling subscriber while waiting for the called station to answer. On hanging up, the release is the same as for a normal connection.

Dayton also had use for the connector which can select one of a number of trunk lines, and the wiring which was devised is shown in Fig. 88. In its local rotating features it differs quite a little from the Chicago switch. The relation of the vertical relay to vertical magnet, rotary magnet, and ringer relay is the same as in the regular Dayton connector. But the rotary magnet is provided with an individual interrupter, A, not permanently wired into its own circuit, but carried through the back contact, B, of the interrupter relay, and the front contact, C, of the private magnet, ready to be connected to lever 4 of the side-switch. The rotary relay controls the private magnet, but not directly, since it does it through the interrupter relay. The second contact on the rotary relay connects the release magnet to the contact of the vertical relay. The connections and functions of the back release relay and the back signal relay are the same as in an ordinary connector.

The call number of any office which has a plurality of lines always ends in the digit "one." Thus for instance "2481." In reality there are a number of trunks available, as 2481, 2482, 2483, etc. The thousands and hundreds digits are handled as usual by the first and second selectors. The tens impulses operate the vertical relay of the special connector, Fig. 88, and by means of the vertical magnet lift the wipers to the desired level. The rotary impulse pulls up the rotary relay, interrupter relay, and the private magnet, but the only result is the stepping of the side-switch over to the middle position.

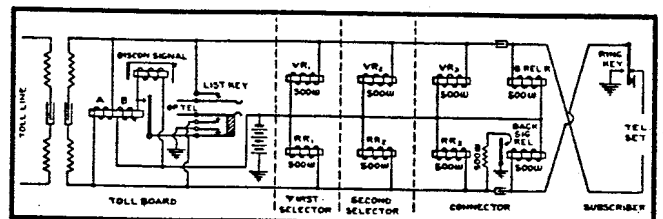


Fig. 87. Schematic of Toll Connection in Dayton System.

At 1 and 2 nothing of interest happens. At 3 the private wiper is connected to spring D of the private magnet. The units impulse, "one", pulls up the vertical relay, which now grounds the rotary magnet and rotates the wipers onto the first line. The succeeding ground on the rotary line pulls up

the interrupter relay and the private magnet. This causes spring *D* of the private magnet to touch contact *E*, connecting the private magnet winding to the private wiper. If the first line is not busy, the private wiper will be on an open contact. But if busy it will be grounded, so that current will flow through the private magnet, holding it up.

When the rotary relay falls back, it lets the interrupter relay do the same. Contact *B* of the latter now connects the rotary-interrupter, *A*, through contact *C* on the private magnet to the rotary magnet. The rotary magnet now pulls up, moving the wipers onto the next line, the finger, *F*, holding the private magnet armature while the private wiper slips from one contact to the next. Having broken its own circuit, the rotary magnet falls back to catch a new tooth on the ratchet cylinder, and rotates again till a non-busy line is found. The non-busy private contact being open will allow the private magnet to fall back, snapping the side-switch into the third position. At lever 4 this cuts off the rotary magnet, stopping rotation. The rest need not be described, being the same as in the ordinary connector.

If all the lines are busy, the wipers will be rotated to the first set of contacts beyond. These special local rotating connectors are in a group corresponding to their hundred and all their banks are multiplied together. If on a certain level there are five lines to a certain subscriber, the sixth contacts are connected to the busy tone. The corresponding private contacts on each connector are disconnected, so that any number of wipers may stop at the same time on the sixth point and get the busy tone.

The arrangement of connectors with regard to first selectors is given in Fig. 89. At the left is the outline of a first selector, showing only enough of the wiring and apparatus which will be described. It is one of 100 first selectors, each of which belongs to a subscriber and is used by him only for originating calls. The banks are all multiplied together. The private wires end in the group, but the vertical and rotary lead away to the second selectors, and are called trunks.

At the right is the skeleton of a connector, one of ten, whose duty is to take all incoming calls to the hundred subscribers whose first selectors are at the left. From each first selector run three normal lines, private, vertical, and rotary, which are multiplied to the banks of the ten connectors at the right. The vertical and rotary normals run from contacts on side-switch levers 2 and 1, so that when the subscriber makes a call they will be cut off and absolutely prevent interference. The private normal runs from the private wiper and shares its condition. Thus when the subscriber originates a call and has found a trunk to a second selector, side-switch 3 of the first selector slips onto its last contact, grounding the private

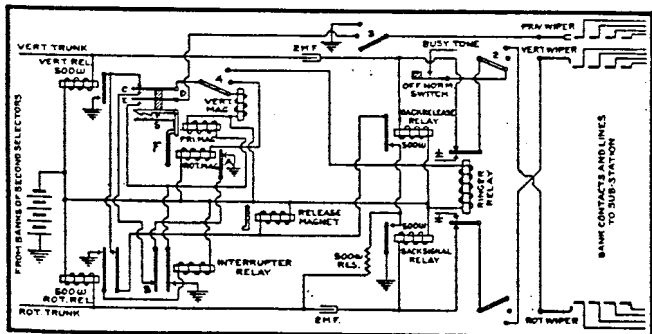


Fig. 88. Connector of the Local Rotating Type, installed at Dayton.

wiper. The private normal shares this ground, so that in all the connector banks the private contacts corresponding to this line will be grounded, thereby forming additional protection from incoming calls.

When a call is received by a subscriber it comes through

one of the connectors at the right. In making the connection, side-switch lever 3 rests on its middle contact to test the line and then slips onto the third point to get ground. Since it has found the line not busy, the side-switch lever 3 of the first selector will be in the normal position as shown in Fig. 89.

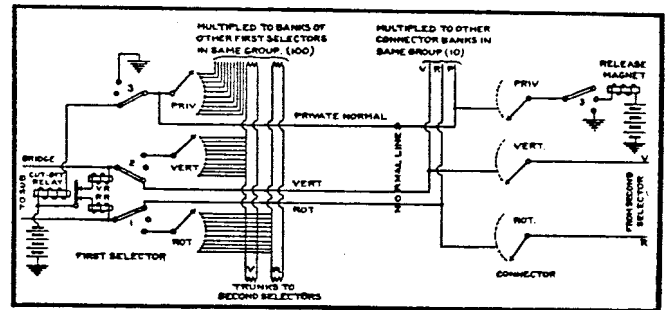


Fig. 89. Relation Between Connectors and First Selectors, Dayton.

Hence the bridge cut-off relay will pull up, cutting battery off the vertical and rotary relays of the first selector. This clears the called line for ringing.

26. The Grand Rapids System

Shortly after the Dayton, Ohio, plant was put into operation the exchange at Grand Rapids, Mich., was installed. While not differing enough from the Dayton board to merit a technical description, it is a more famous one, having been made a landmark in automatic telephony all over the world. Perhaps the most widely known words in this connection have been "Fall River, Mass." and "Grand Rapids, Mich.," the former to show how long the automatic has been a success, the latter as an example of modern progress. Grand Rapids especially has been a bone of contention between the two camps, manual and automatic, and some very contradictory statements about it have been made by different persons. The Citizens' Company, which operates it, has always been energetic and businesslike and has endeavored to cooperate with the Automatic Electric Company in making the automatic a success. Visitors are shown its workings the year round, and the exchange from the start has been considered a model and counted the pride of the town.

27. The Los Angeles Multi-Office System

During the installation it was noticed that in some cases there was difficulty in releasing, especially on long lines having ground rods in earth for ground return. This was found to be due to the relatively heavy current required to operate all six 500-ohm line relays at the same time, the current from all going through the one ground rod and its contact with earth. Mr. A. E. Keith suggested to the other engineers the desirability of cutting off all the relays except the last pair, but there was no time then to work out the details. Later this suggestion resulted in the production of the release trunk selector, which was embodied in part in the South office at Los Angeles, Cal., which has since become as famous as Grand Rapids.

The Los Angeles installation merits our special attention for two reasons, the beginning of the trunk release and the operation of automatic and manual interchangeably in the same exchange. Each of these features is very interesting and their provision called for a high character of engineering ability.

When the Home Telephone Company, of Los Angeles,

started, a Kellogg common battery multiple switchboard of 18,000 lines capacity was purchased. As only 7,049 lines were necessary to meet the need at that time, it was thought that the board was ample for all time to come. But within two years after beginning service on the board 10,000 lines were in use and the number still growing. The great expense of

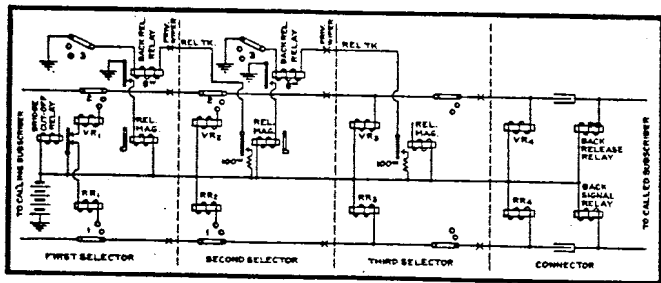


Fig. 90. Theoretical Diagram of Trunk Release.

adding to a 10,000 line multiple is a serious matter, and the rentals were not large enough for the expense to be ignored. It was decided, therefore, to restrict the main office chiefly to telephones in the business district, and to serve the rest of the city from branch offices. As a beginning of this plan the South office, two and one-half miles south of Main office, was erected to relieve the latter of about 2,000 lines. It was planned for a manual board. But the inspection of the exchanges at Dayton, Ohio, and Grand Rapids, Mich., caused the manual to be abandoned, and automatic equipment was ordered.

Here the engineers showed their foresight in designing the South office equipment to fit into an automatic system which should later cover the entire city, at that time (1904) having a population not far from 150,000. Hence, although the South office contained only 2,000 lines, the automatic equipment for it was designed on the plan of a 100,000 line exchange. All the numbers from 1 to 19,000 were reserved for the Main office, and from 21,000 to 29,999 were set aside as the ultimate capacity of the South office. Subscribers in the latter were to select each other entirely automatically, all the numbers beginning with "2," which was to be the designation of that office. To call a manual subscriber the automatic subscriber was to pull "1" on his dial, which would trunk him to "B" operator in the Main office to whom he would give his number orally. She would complete the connection with a plug-ended trunk. For calls from manual to automatic two plans were proposed. A trunking section was to be installed

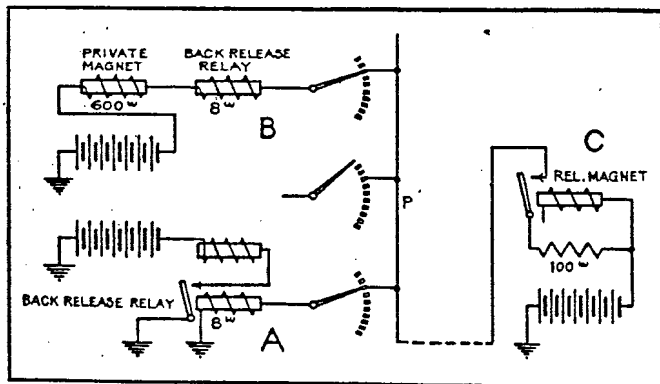


Fig. 91. Relation of Back Release Relay to Private Magnet.

in the South office, so that during the busy part of the day calls could be trunked from Main to South by ordinary trunks. The "B" operators in the latter office were to have in front of them a multiple of all the South office subscribers' lines, and could complete the call by plugging directly into them. But at night the South office "B" operators were to

be dispensed with and the numbers called automatically by special trunking operators at the Main board.

The work on the South office was begun in May and completed during July, 1904. We will consider first the equipment for completing local calls within the South office. As our interest naturally centers on the trunk release, Fig. 90 is given, which shows this feature of a completed connection. The lines come in from the calling station at the left and go through first, second and third selectors and connector to the called station at the right. It will be observed that the connector is of the ordinary bridging form, so that there is no third wire between it and the third selector. It is released by the simultaneous action of the vertical and rotary relays. The third selector is released in the same way, so that while talking there are three bridges across the circuit.

The release magnet in the third selector has a contact which feeds battery through a 100-ohm resistance to the release trunk leading back to the bank of the second selector. In the latter it passes through the 8-ohm back release relay to ground. This relay operates the release magnet of the second selector. In the same way this release magnet has a contact which may feed battery through 100 ohms to the 8-ohm back release relay in the first selector and to ground.

The act of releasing is as follows: The calling subscriber, in hanging up, temporarily grounds both vertical and rotary lines. In the first and second selectors this causes no action

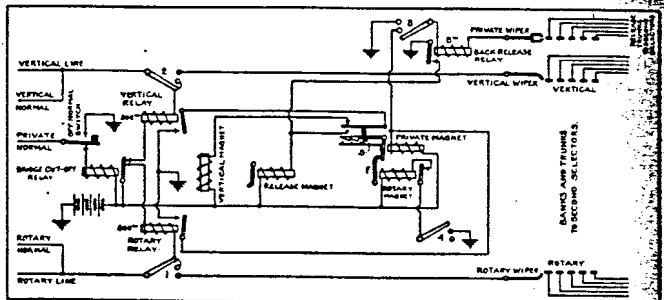


Fig. 92. First Selector with Trunk Release, Los Angeles.

since at this time the lines are clear of all relays. In the third selector and connector the vertical and rotary relays pull up simultaneously, and in each this energizes the release magnet. In the third selector the release magnet not only releases the switch, but also feeds battery over the release trunk to the second selector, pulling up the back release relay. The latter grounds the release magnet of the second selector, releasing that switch. This release magnet also feeds battery over the release trunk to the first selector, operating its back release relay, which controls the release magnet. In this way, by five circuits, linked by relays and magnets, the release is accomplished without using relays across the circuit in each switch.

It is evident that this principle could have been carried farther, so that the third selector would have been released by a third wire from the connector. That it was not done is explained by the fact that when the system was first designed the trunk release had not been completed. When done, the first, second, and third selectors were changed to the third wire plan, but to make over the connector would have necessitated too great changes.

The presence of the back release relay in the private wiper calls for certain consideration. During the time that the private wiper is used as a feeler for a non-busy line, current flowing from battery will pass through the private magnet, back release relay, and private wiper to ground. This must pull up the private magnet, but not the back release relay. Hence the latter was wound to a relatively low resistance, 8 ohms, and made not very sensitive, while the private magnet was made about 600 ohms.

After the trunk has been selected the back release relay stands between the private wiper and ground. Other first selectors, in hunting non-busy trunks on the same level, will pass their private wipers over the multiples of this contact as shown in Fig. 91. *A* is a first selector, and occupies the third trunk. The second selector in which this trunk ends is *C*. The release trunk only is shown and the first two private bank contacts are supposed to be busy, i. e., grounded. *B* is the private portion of another first selector which is hunting a non-busy trunk to the same group. At this instant it is passing over the multiple of the private contact which *A* occupies. As far as the feeler of *B* is concerned the private wire, *P*, must be grounded, so that its private magnet will remain energized until its rotary magnet steps the wipers over to the next contact. But between *P* and the ground which makes it busy is the 8-ohm relay, and it is to prevent the testing current from pulling it up and causing premature release that it is made of low resistance and relatively insensitive. On the other hand, when the release magnet of the second selector, *C*, is pulled up for the disconnect, the back release relay must pull up reliably. The larger current necessary is furnished by the 100-ohm resistance.

Fig. 92 gives the detail wiring of the first selector. The vertical and rotary relays are wired to the side-switch so as to be cut off when the switch has selected its trunk. The rotary relay, as usual, controls the private magnet. The vertical re-

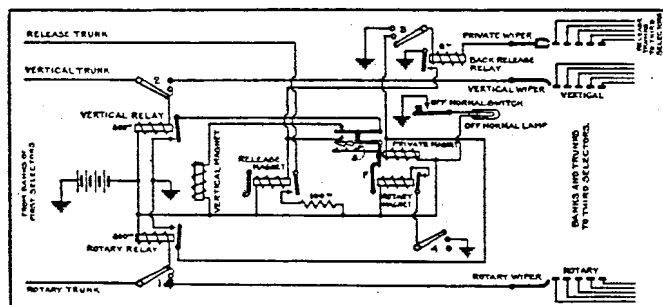


Fig. 93. Second Selector with Trunk Release, Los Angeles.

lay operates the vertical magnet, or if the private magnet is simultaneously energized by the rotary relay it will pull up the release magnet. This latter is the method of release if necessary to disconnect from a partly completed call, where the side-switch failed to go into the third position. The mutual relations of side-switch, private magnet, and rotary magnet need not be detailed here, having been fully described in connection with the Chicago system.

The bridge cut-off relay winding and private normal are not worked in connection with the private wiper, as in the Dayton board, on account of the back release relay. Instead, the private normal is carried to the main spring of the off normal switch, and through the back contact is normally connected to the bridge cut off relay. Thus incoming calls will be able to ground the private normal at the connector bank (as at Dayton, energize the bridge cut-off relay, and clear the called line for ringing. But if this first selector makes a call, the first upward motion of the shaft will move the off normal switch, disconnect the bridge cut-off relay, and ground the private normal, which protects the line from calls coming in through the connector. The vertical and rotary normals are tied permanently to the vertical and rotary lines, so that the ground on the private normal is the only protection against the interruption. But it has proven in practice to be ample protection.

Fig. 93 shows the second selector, which is very much like the first selector, except that there are no normal lines, and the release magnet has a contact which may connect battery through 100 ohms to the release trunk leading back to the first

selector bank. The off normal switch works an off normal lamp to show the attendant when the switch is occupied.

The third selector, Fig. 94, has the vertical and rotary relays permanently bridged, since there is no release trunk from here to the connector. There is no back release relay. The other features are the same as the second selector.

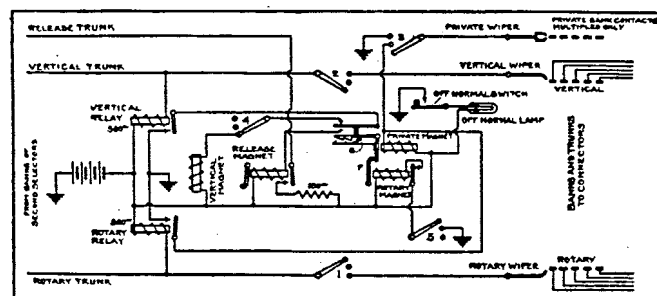


Fig. 94. Third Selector, South Office, Los Angeles.

The connector, Fig. 95, is the same bridging type as used at Dayton. The rotary relay controls the private magnet. The vertical relay normally operates the vertical magnet, rotary magnet, or ringer relay, according to the position of the side-switch. In releasing from the calling end, the vertical relay furnishes ground and the private magnet and rotary relay connect it to the release magnet. The called subscriber has a back signal relay which in connection with the back release relay may be used for releasing.

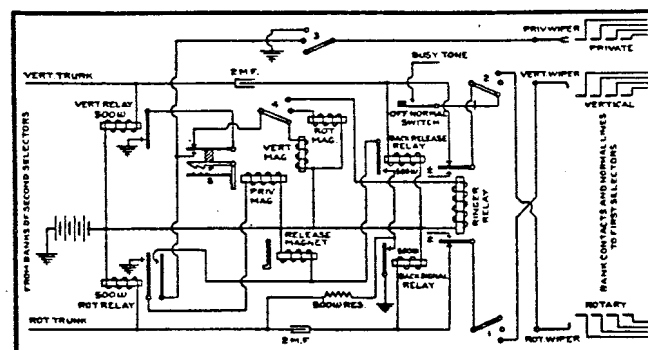


Fig. 95. Connector, South Office, Los Angeles.

As previously stated, during the busy portion of the day all calls from Main (manual) to South (automatic) are trunked directly from the "A" operators at the former to "B" operators at the latter office, and that these "B" operators have access to the subscribers' lines. Fig. 96 gives the scheme of a complete connection from manual to automatic. At the left is the calling end of a Kellogg subscriber's operator's cord, with the usual calling supervisory relay, *C. S. R.*, and calling control relay, *C. C. R.*, the former feeding positive battery to the tip, the latter negative battery to the sleeve.

Each "A" operator has access to the multiple of a number of

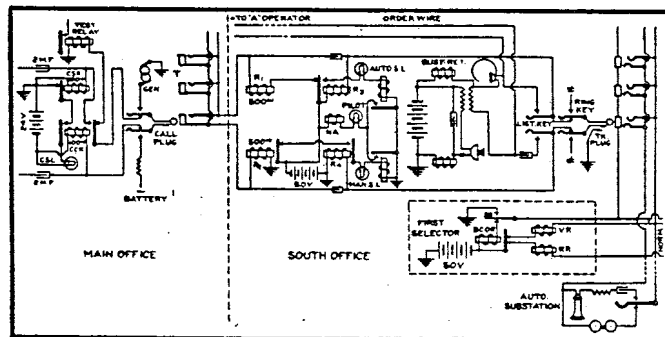


Fig. 96. Circuit Set-up for Day Trunking, Manual to Automatic, Los Angeles.

outgoing trunks, *T*, leading to the South office. The sleeve of each trunk is permanently tied to earth through the retardation coil, *R*. The tip line is normally connected through retardation coil, *R*₂. The tip line is normally connected through retardation coil *R*₂ and the back contact of relay *R*₂ to 50 volt battery. Two 2 m. f. condensers separate the trunk into two

parts. The tip of the called end receives negative battery through the winding of relay *R*₂, while the ring gets ground, or positive, battery through the winding of relay *R*₁. The talking circuit runs through the regular listening and ringing key to a three conductor plug, whose sleeve is connected "dead" to ground. The operator's set is like the ordinary common battery set, except for the connection of a high resistance retardation coil, *Busy Ret.*, between negative battery and the point between the receiver and secondary of the induction coil. This is for the busy test. The subscriber's multiple consists of banks of 3-conductor jacks, whose tip and ring are tapped to the vertical and rotary normal lines and the sleeve to the private normal of the automatic subscriber.

Let us trace a call through for the purpose of making the action clear. The subscriber at Main office calls central as in any manual common battery exchange and gives the number to the operator. Finding that it is for the South office the "A" operator presses an order button and gives the number directly to a "B" operator in the South office. The latter assigns the trunk. The "A" operator then makes the busy test on it, touching the tip of the calling plug to the sleeve of the jack. If free, there is no current flowing through *R*₂, hence the sleeve will be at ground potential, which is the same as that of the busy relay of the "A" operator.

Finding the line free she plugs in. At once negative current from the 24-volt battery flows through the calling control relay, *C. C. R.*, to sleeve, along sleeve trunk to South office and through *R*₂ to ground. At the Main office this pulls up the calling control relay, *C. C. R.*, disconnecting the busy test relay and closing up the tip side of the cord circuit. At the South office *R*₂ pulls up and breaks its contact. The current flowing through *R*₂ changes the potential of all the sleeves of this trunk at Main office, so that any other "A" operator will get the busy test on attempting to use it. At the South office the back

contact of *R*₂ feeds negative battery at 50 volts through *R*₁, tip line to Main, calling supervisory relay, *C. S. R.*, to ground. This keeps the calling supervisory lamp, *C. S. L.*, from lighting.

The "B" operator at the South office tests the called line by touching the tip of the trunk plug to the sleeve of the multiple jack. Here the non-busy condition is full negative battery, 50 volts from ground, the positive battery terminal being grounded.

Since the operator's receiver is wired through a retardation coil to negative battery no current can flow. But if the called line is occupied, the private normal will be grounded, hence current will flow through the operator's receiver giving the busy click.

Finding the line free she inserts the trunk plug in the subscriber's jack. The sleeve of the plug puts "dead" ground on the private normal of the called line's first selector, which operates its bridge cut off relay, *BCOR*, cutting off battery and clearing the line for ringing. This ground on the private normal also protects against other automatic switches.

The automatic substation set was wired as at Dayton, Ohio, with the exception of a condenser, which was cut in series with the receiver as shown in the drawing at the right. On the insertion of the trunk plug current flows from ground battery through *R*₂, ring of trunk plug, one side of line to subscriber's set, through the bell, back on the other line wire to tip of plug, through *R*₂ to negative battery. This energizes both *R*₂ and *R*₁. *R*₁ makes its contact, but as *R*₂ is energized it does nothing. *R*₂ pulling up switches battery from *R*₁ to the automatic supervisory lamp, *Auto. S. L.* This de-energizes the calling supervisory relay, *C. S. R.*, at Main office, lighting the calling supervisory lamp, *C. S. L.*, so that the "A" operator knows that the connection is established. The lighting of the automatic supervisory lamp at South office serves as a ringing lamp to the "B" operator, who rings the called subscriber with a manual key.

When the automatic subscriber answers, the bell is cut out and the receiver with its secondary and condenser cut in. The latter at once stops the flow of current, allowing both *R*₂ and *R*₁ to fall back. The latter causes no change. *R*₂ switches negative battery from the automatic supervisory lamp (putting it out) to *R*₁, thus energizing the calling supervisory relay at the Main office and putting out the calling supervisory lamp, *C. S. L.* Thus both operators are notified that the called subscriber has answered.

When through, the automatic subscriber hangs up. This lights both the automatic supervisory lamp, *Auto S. L.*, at South office and the calling supervisory lamp at Main. The Main operator pulls down the connection which lets *R*₂ fall back, giving battery to the manual supervisory lamp, *Man. S. L.*, since *R*₁ is again energized by the current through the subscriber's bell. Seeing both lamps lighted, the "B" operator pulls down the trunk.

The arrangement for night trunking from Main to South is shown in Fig. 97, which gives the apparatus in the former office. Special trunking positions are provided at one section of the board, and each position is equipped with part of the total number of trunks to the South office. Multiplied in front of all the "A" operators in the Main office are local trunks, *T*, leading to the special trunking position, the total number of trunks being divided among the different positions. The order wire attached to the head telephone of each trunk operator is

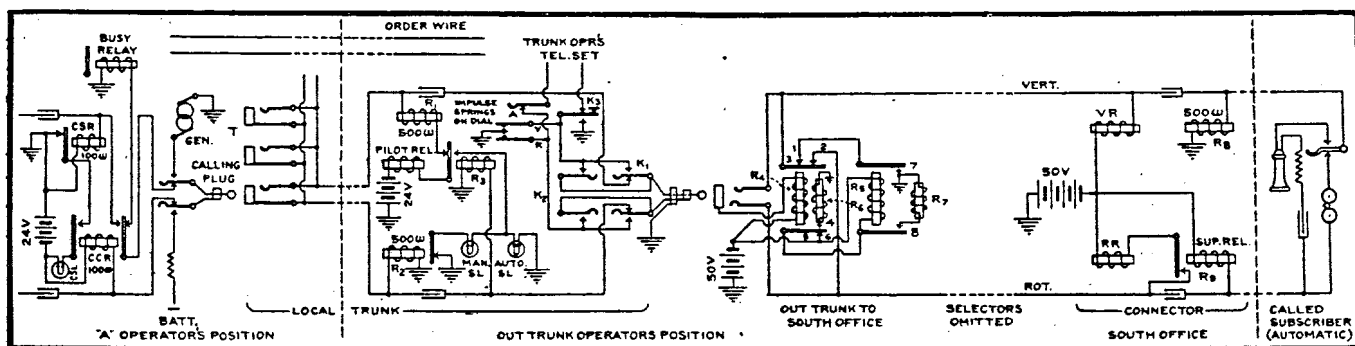


Fig. 97. Connections for Night Trunking, Manual to Automatic, Los Angeles.

multipled to the order buttons of part of the "A" operators. At the left in Fig. 97 is the calling end of a Kellogg cord circuit with the usual equipment. The tip of the local trunk, T , runs through the retardation coil, R_1 , back contact of relay R_2 , pilot relay to negative battery. The sleeve goes through relay R_2 to ground. On the automatic side of the condensers the tip line has no normal connections. The ring side is connected through R_2 to ground. The latter may be called the supervisory relay of the trunk, since it not only operates the supervisory lamps at the trunking section, but also repeats the automatic supervision to the "A" operator.

The outgoing trunk is equipped with two relays, R_4 and R_5 . The former is a cut-off relay and is quick-acting. Normally its main spring, 3, with back contact, 2, keeps the circuit "dead short." R_5 is slow acting and has for its function the grounding of the lines through its contact 7.

On receiving a night call for the South office the "A" operator, by means of an order wire, repeats the number to one of the out trunk operators. The latter assigns the local trunk, T , to be used, into which the "A" operator inserts the calling plug of the cord circuit which she is using. In the sleeve side, the calling control relay, CCR , at the "A" position, and R_2 at the trunking position pull up. In the tip side, ground battery through the calling supervisory relay, CSR , at the "A" board flows over the trunk, through R_1 , pilot relay to negative battery. In consequence of this the calling supervisory lamp, CSL , does not light.

The trunk operator at the same time selects a trunk to the South office and plugs in. The sleeve of plug carries ground, which causes R_4 to pull up, thereby removing the short circuit from the line. At the same time main spring 5 closes with contact 4, causing R_5 to pull up, the latter locking in position through its own contact 8 and the retardation coil R_1 .

The trunk line ends in the South office in a second selector, it not being necessary to go through a first selector, since the function of the latter is to pick out the office. The second and third selectors and connectors used for incoming calls were installed as a separate trunking section in the switch room of the South office. They were of the trunk release type.

After plugging into the trunk to the South office, for a moment current will flow from the second selector over the rotary line to the ring of the local trunk plug and to ground through R_4 . This pulls up and lights the automatic supervisory lamp, $Auto. S. L.$ The "B" operator throws key K_1 , which cuts off the circuit behind and connects the operator's dial and telephone set to the outgoing trunk. This gives a clear line over

which to signal and operate successively the second selector, third selector, and connector at the South office. The contact A opens while the dial is being turned, the same as in a regular automatic substation.

In Fig. 97 the selectors have been omitted and a bare skeleton of the connector and called station shown. When the called

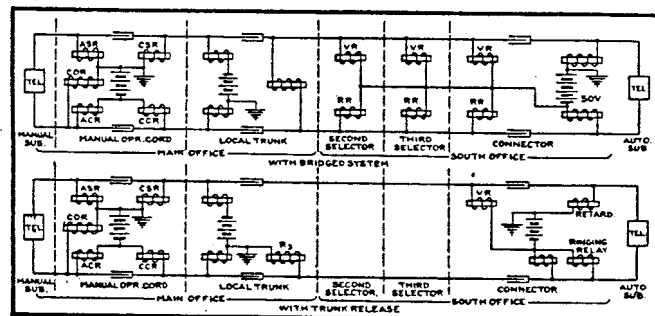


Fig. 98. Talking Conditions of Night Trunking Circuit, Manual to Automatic, Los Angeles.

station has been selected, the operator presses the key K_2 , which grounds the vertical line and rings, after which K_1 is released, closing up the tip-vertical line. Subsequent ringing may be done by the listening key, K_3 , and the ringing key K_4 . While waiting for the called subscriber to answer, the connector feeds battery current through the 500 ohm retardation coil, R_6 , and the supervisory relay, R_3 , to the bell at the called station. R_3 pulls up, connecting the rotary relay, RR , and negative battery to the rotary line. This feeds current to R_3 at the Main office energizing it and lighting the automatic supervisory lamp, $Auto. S. L.$ When the automatic subscriber answers, the condenser in the telephone circuit stops the flow of current, letting R_6 and R_3 fall back. This puts out the automatic supervisory lamp, notifying the "B" operator that the called subscriber has answered. It also feeds negative battery through R_1 to the calling supervisory relay, CSR , in the manual cord, energizing the latter. This extinguishes the calling supervisory lamp. CSL , and gives notice to the "A" operator. The pilot relay will not energize through the 600 ohms to which it is connected.

When the conversation is completed, both subscribers hang up. The calling (manual) subscriber lights the answering supervisory lamp as usual. The called subscriber (automatic) by hanging up closes the circuit through his bell, thereby energizing R_6 in the connector. This closes battery through the rotary relay to the rotary line which pulls up R_4 at the Main office. On pulling up, R_4 lights the automatic supervisory lamp which lets the trunking operator know what has happened. When the armature of R_4 breaks away from its back contact, it cuts battery

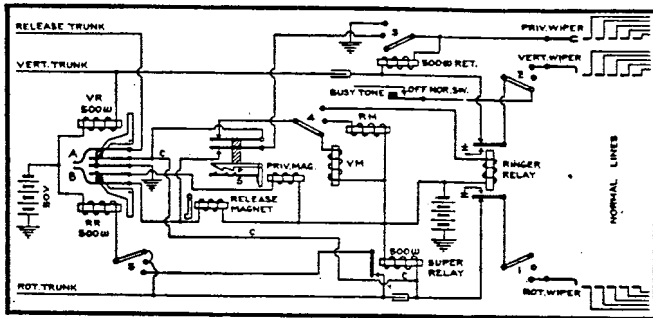


Fig. 99. Supervisory Connector with Trunk Release, South Office, Los Angeles.

off the tip wire, allowing the calling supervisory relay on the "A" operator's cord circuit to fall back, lighting the supervisory lamp. Thus both operators have simultaneous notice that the automatic subscriber has hung up.

When the "A" operator pulls down the connection she causes R_2 to fall back, lighting the manual supervisory lamp, *Man. S. L.* Seeing both lamps lighted, the trunking operator removes the local trunk plug from the outgoing trunk jack. The simple removal of the plug from the jack causes the release of the automatic switches in the South office as follows: The sleeve of the trunk plug, carrying ground, has been the means of holding up R_4 . The latter now falls back quickly and short circuits the vertical and rotary lines at 2 and 3. Since contact 7 on R_6 is still made, this grounds both lines. The armature No. 5 has meantime swung away from contact 4 (ground) and now touches 6, which is negative battery. This places a "dead short" on relay R_6 , so that it starts to fall back rather slowly. When it has fallen back, contact 7 opens, removing the ground from the lines. This completes the release of the automatic switches in the South office.

It is interesting to notice the new circuit which this trunking gives us for talking. This is shown in Fig. 98. The upper diagram shows the conditions which would have existed if the bridged system had been used. The lower shows the Los Angeles condition, due to the trunk release. Counting the relays on the manual cord circuit there would be eight bridges across the line, in addition to the cut-off relay, *C.O.R.*, of the manual subscriber, which goes to ground. By the trunk release this is made only five bridges, plus the cut-off relay and R_2 in the local trunk.

The second selector in which the trunk line terminated in the South office was like those used by the South office subscribers (See Fig. 93, *Telephone*, Vol. 17, No. 11, Page 303), except that the 100 ohm resistance at the release magnet was omitted, together with the release trunk to which it fed current. The

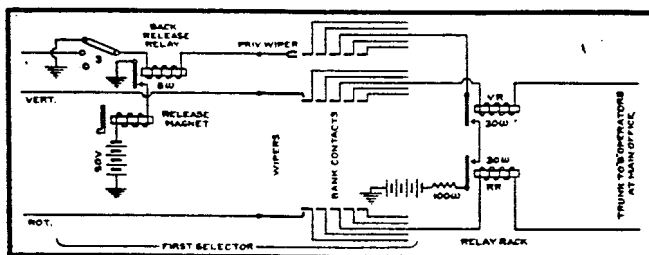


Fig. 100. Outline of Trunking Circuit, Automatic to Manual, South Office, Los Angeles.

third selector was like the ordinary second selector, arranged for complete trunk release.

The supervisory connector used on this scheme of trunking was wired as shown in Fig. 99. It is of the full trunk release type and feeds release current back to the third selector through the special front release springs, *A B*, and the release magnet itself is utilized to limit the flow of current instead of a special resistance. The supervisory feature consists of the 500 ohm supervisory relay feeding negative battery to the rotary line and a 500 ohm retardation coil from the vertical line to the private wiper. In the talking position this fed positive or ground battery to the called subscriber.

The supervisory relay has one contact, which controls the connection of the rotary relay to the rotary line. This operates the supervision at the manual board, which was above described. The wire *C.C.C.* was put in to balance the two sides of the talking circuit with respect to ground. It connects the ringer relay to the rotary line, which without it would have only one inductive leak to earth. It must be remembered that in dealing with the talking qualities of telephone circuits the impedance from the two sides to earth must be as nearly equal as possible. And as far as inductive balance is concerned the retardation coils may as well be connected to negative battery as to ground since the characteristics of alternating current is not affected by passing through battery. It acts as a very low non-inductive resistance. This accounts for the presence of the ringer relay connected to the rotary line in Fig. 98, lower sketch.

Mention has been made in the previous chapter of the method of handling calls from automatic to manual. The automatic subscriber merely pulls "one" on the dial, which raises the wipers of his first selector up to the first level and selects a non-busy trunk to a "B" operator at the main switchboard. Since the first selector is trunk release, the vertical and rotary relays are cut off when the side-switch slips into its third position. This leaves the subscriber without means of releasing. To obviate this difficulty each trunk line to Main was provided with two special series release relays, installed on the relay rack in the South office. They are wired as shown in Fig. 100. Each relay is wound to 30 ohms resistance and has a copper sleeve over its iron core, so that it offers as little impedance as possible to talking current. Running from battery to the contact of the rotary relay, *R. R.*, is a 100 ohm resistance. The release line is continued through the contact of the vertical relay, *R. R.*, to the private banks of the first selectors. On release, both relays pull up simultaneously and operate the release magnet through the back release relay over the release trunk.

Since the first installation described in these two chapters additional exchanges have been put in, all automatic, following the scheme of ultimately covering the entire city with automatics as fast as traffic calls for increased facilities. The problems brought out by the multiplicity of offices and long trunks have called for additional inventions, which really come later in the logical development of the history.

28. The Battle Creek System

The trunk release which was tried out at Los Angeles was so successful that it was improved. As is usual, the improvement consisted in a simplification of the release circuit cutting down the number of circuits which were linked together from the first selector to the connector. The first installation of this improvement was at Battle Creek, Mich., in 1904. It was a 10,000 system and had first

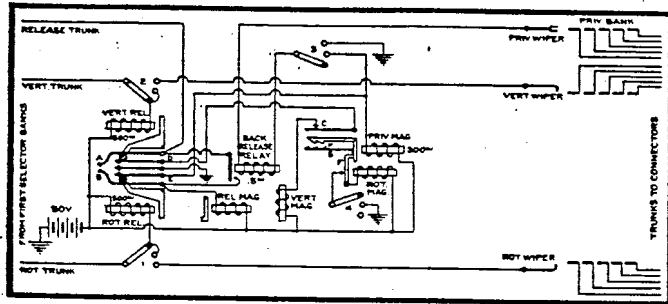


Fig. 101. Battle Creek Second Selector, with Improved Trunk Release.

selectors, second selectors, and connectors. The first selector was identical with that at Los Angeles, except that the back release relay (in the private wiper) was made 0.5 ohm instead of 8 ohms. This reduction was made to give a greater margin of safety, since the back release relay must not pull up when in series with the private magnet testing for a non-busy trunk.

The second selector is shown in Fig. 101. The rotary relay as usual controls the private magnet. The vertical relay contact, *D*, controls the vertical magnet through contact *C* on the private magnet. The feeler for a non-busy trunk is composed of the private wiper, back release relay, and the private magnet, connected to negative battery; but the half-ohm back release relay will not act

that if either relay be energized alone the contact will not quite be made. But if both vertical and rotary relays be pulled up at once, *A* and *B* will meet, closing the gap in the release line. This is the means used for releasing from uncompleted connection. If for any reason the second selector fails to complete its cycle of operations, or after pulling the first digit the subscriber decides not to complete the call, he may get away by merely hanging up his receiver. This grounds the vertical and rotary lines closing *A-B*. Negative battery will then flow through momentarily. The vertical and rotary relays will pull up the release magnet, contacts *A-B*, release trunk, private wiper of first selector, its back release relay, and lever 3 of the side-switch, to ground. The release magnet of the second selector and the back release relay of the first selector are thus energized, the former releasing the second selector, the latter operating the release magnet of the first selector, which performs a similar duty in that switch.

The back release relay in the second selector has its contact wired in parallel with the contact *A-B* in the release trunk. This allows it to act on the release magnet and release trunk at one operation and is a marked advance in simplicity over the plan followed at Los Angeles.

The connector wiring is shown in Fig. 102. The rotary relay controls the private magnet. The vertical relay operates the vertical magnet, rotary magnet, and ringing relay, depending on the position of side-switch 4. Its contact wire, *M*, is looped through a contact, *C*, on the private magnet to avoid moving any of the three above-named magnets while releasing. The busy test on the called line is made by means of the release magnet. When the called has been selected, the last rotary impulse pulls up the rotary relay and the private magnet. Side-switch 3 is resting on the middle contact so that when the private mag-

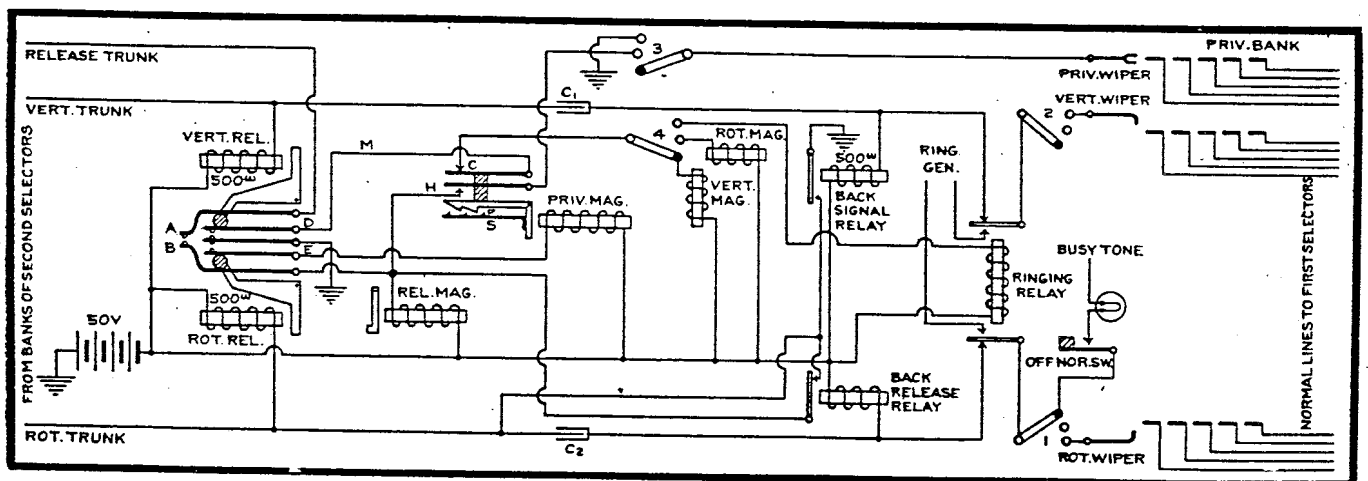


Fig. 102. Connector with Improved Trunk Release, Battle Creek.

net is pulled up negative battery is connected through the release magnet to the private wiper. If the latter is resting on ground, due to a busy condition, the release magnet will pull up, instantly releasing the connector.

Not knowing that this has happened, the subscriber will press the ringing button, grounding the vertical line. As the side-switch and wipers are now again in their normal

net is pulled up negative battery is connected through the release magnet to the private wiper. If the latter is resting on ground, due to a busy condition, the release magnet will pull up, instantly releasing the connector.

Not knowing that this has happened, the subscriber will press the ringing button, grounding the vertical line. As the side-switch and wipers are now again in their normal

condition due to the release, this act of attempting to ring will step the wiper shaft up one or more notches. This closes the off-normal switch, which connects the busy tone to the rotary line through side-switch 1. While waiting for the called station to answer, he will hear this tone, and will thus be informed that the line is engaged.

The release after conversation is made through the con-

of Los Angeles. (Fig. 90, ~~of Los Angeles~~) In Fig. 103 it will be seen that the release of all the switches is started by the joint action of two relays, the vertical and rotary in the connector, all the relays in the selectors being cut off the line. When the toll operator removes her cord plug a momentary grounding of both vertical and rotary lines takes place, as has

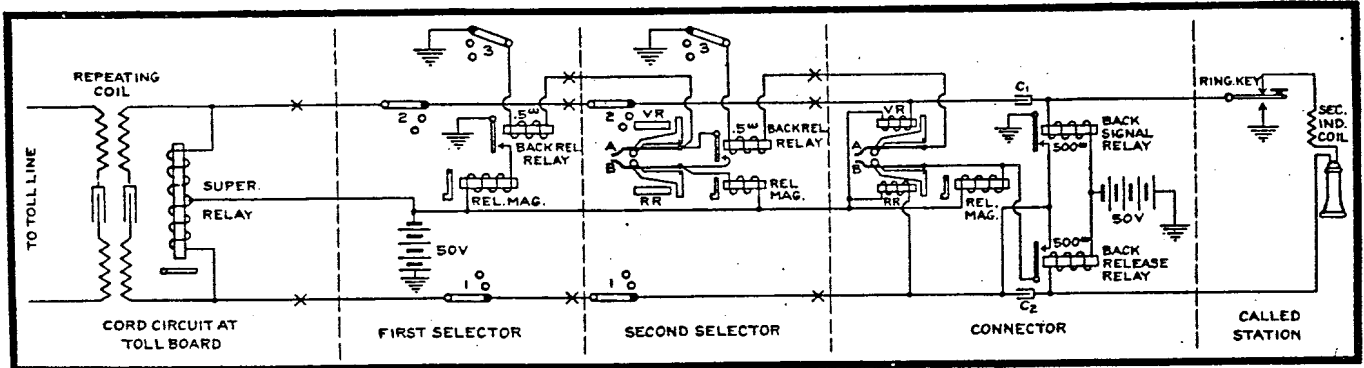


Fig. 103. Scheme of Trunk Release, Battle Creek.

tact *A-B*, as described for the second selector. The called subscriber can also release himself from the connection by hanging up, if he has previously rotated his dial one number or more. In hanging up, he will energize both the back signal relay and the back release relay, thereby pulling up the release magnet. The circuit path over which this takes place is as follows: From negative battery through the release magnet, to the right to the contact of the back release relay, up to the contact of the back signal relay and thence to ground.

The back signal relay is used alone for the purpose of signaling a toll operator. When an automatic subscriber desires a toll connection, he calls the toll desk by pulling a certain number on his dial. The toll operator answers, takes the details of the call, and informs the subscriber that he will be called as soon as the line is ready. When she has put the call through and the called party in the distant city is on the line, the toll operator with her dial selects the local subscriber and rings him with a button.

When the local subscriber answers, she directs him to pull "one" on his dial. He is then ready to proceed with the conversation. This single pull is to let down the ground spring in his instrument, so that when he supervises or hangs up, he will have ground connection to work with. At any time during the toll conversation he may signal the toll operator by pressing his ringing button. Fig. 103 shows a skeleton of the whole connection from the repeating coil in the toll cord at the left, through first selector, second selector and connector to the called station at the right. It will be noticed that from the repeating coil to the subscriber there are three bridges across the circuit, the supervisory relay on the toll cord, the vertical and rotary relays in the connector, to the left of the condenser, and the back signal release relays to the right.

When the subscriber wishes to signal the toll operator, he presses his ringing button. This grounds the vertical line and pulls up the back signal relay. This relay puts a dead ground on the rotary line to the left of condenser C_1 , so that current will flow through the rotary relay of the connector and half of the supervisory relay in the toll cord. The former has no effect. The latter pulls up and operates a signal in front of the operator, who gets in on the line and attends to his wants.

This diagram shows the simplicity of the improved trunk release, especially if compared with the first trunk release

been previously described. This causes the vertical and rotary relays in the connector to touch contact *A-B*. Negative battery then flows through the release magnet over the release trunk to the back release relay in the second selector and then to ground. Both pull up, the former linking itself to the detents which hold the wiper shaft. The back release relay (in the second selector) closes the gap in parallel with *A-B*, thereby allowing current to flow through the release magnet over the release trunk back to the back release relay on the first selector on ground, due to a busy condition, the release magnet will second selector to release, while the back release relay of the first release energizes the release magnet of that switch. When the vertical and rotary relays of the connector fall back, opening contact *A-B*, all the relays and magnets in the chain of circuits fall back and the release is complete.

There are three circuits in this chain and they are linked together by the back release relays in the simplest and most natural manner. The talking circuit is as clean as possible, consisting merely of two wires carried through good wiping contacts and a single pair of condensers, with only two bridges and no series coils. The use of the third wire (release trunk) made all this possible, and the improvement certainly justified the expense.

29. Switchroom Layouts

It is natural that in any new system time is required for engineering practice to settle on the best ways of doing things. The automatic switchboard was so different from manual boards that the methods of arranging apparatus and cables which were standard practice with the latter would not fit the former. For some time no very definite practice obtained, each case being wired as thought best at the time. In general, all the first selectors were put in one place, the second selectors grouped by themselves, and the connectors in still another group. This made the wiring somewhat complicated, and made it difficult to trace the course of a call in case a subscriber got "hung up," that is, made a call wholly or in part and could not release.

Finally certain well defined ideas on the grouping of switches began to appear, and this led to the revision of the arrangement of the cables as well. It was seen that inasmuch as the first selectors represented the subscribers' lines, the connectors which serve them with incoming calls should be associated with them, to make the cabling short. Moreover, if the second selectors can be associated in some way with the groups of first selectors which they serve, it will materially aid in simplifying wiring and tracing calls through the various switches.

Finally a plan of layout was devised by Mr. A. E. Keith which solved the matter neatly and economically. Application for a patent was made March 9, 1905, and was issued September 25, 1906, as No. 831876. The general arrangement is shown in Fig. 104, and may be termed a floor plan. The switches are represented by short vertical lines and are in groups, each group being mounted on a frame. There are ten frames in each vertical row and ten rows, making a total of 100 frames. Each frame is intended to represent the switches for serving 100 subscribers and will consist of 100 first selectors, ten second selectors, and ten connectors. Thus the size of the exchange illustrated is ten thousand lines.

The left vertical row of frames constitute the first thou-

sand that is serving all the subscribers whose numbers begin with "1," as "1248," or "1746." The next vertical row to the right is the second thousand, all the numbers beginning with "2," as "2365," or "2906." The last row is the "naught" thousand, and its numbers being in "0." In automatic work, "0" has the meaning of "ten," and is the tenth in any series.

In each vertical row constituting a particular "thousand" the ten frames are arranged in a certain definite order. At the bottom is the "0" hundred or frame; above it come in order the first hundred, second hundred, etc., to the ninth hundred or frame. The "0" frame contains the first selectors of the lines whose numbers are from 1000 to 1099; the first hundred has the numbers from 1100 to 1199; the third from 1300 to 1399, etc. For example, in the first row at the left (the first thousand) the third hundred will be 1300, while the frame adjacent to the right will be 2300, since it is in the second is in the second thousand. In each case, the full number of a frame will be its own hundred number with the proper thousand digit prefixed. The full number of the subscribers whose first selectors are in the third frame of the first thousand will be from 1300 to 1399 inclusive,

while the corresponding frame in the second row or thousand will be from 2300 to 2399 inclusive. We may say, then, that the horizontal rows contain frames of corresponding hundreds, although they are in different thousands.

We now have the proposition of connecting any subscriber in any of these frames to any other subscriber in any frame. Regarding the problem from the automatic point of view, we shall select the desired line in three steps. First, we will pick out the desired thousand, which is the first digit of the number. This duty is performed by a first selector switch. Second, we will pick out a particular frame or hundred-group in that thousand, which is the second digit of the number. This duty is performed by a second switch. Third, we will pick out a certain number in the selected frame, which number is the last two digits in the whole call number. This last duty is performed by the connector switch.

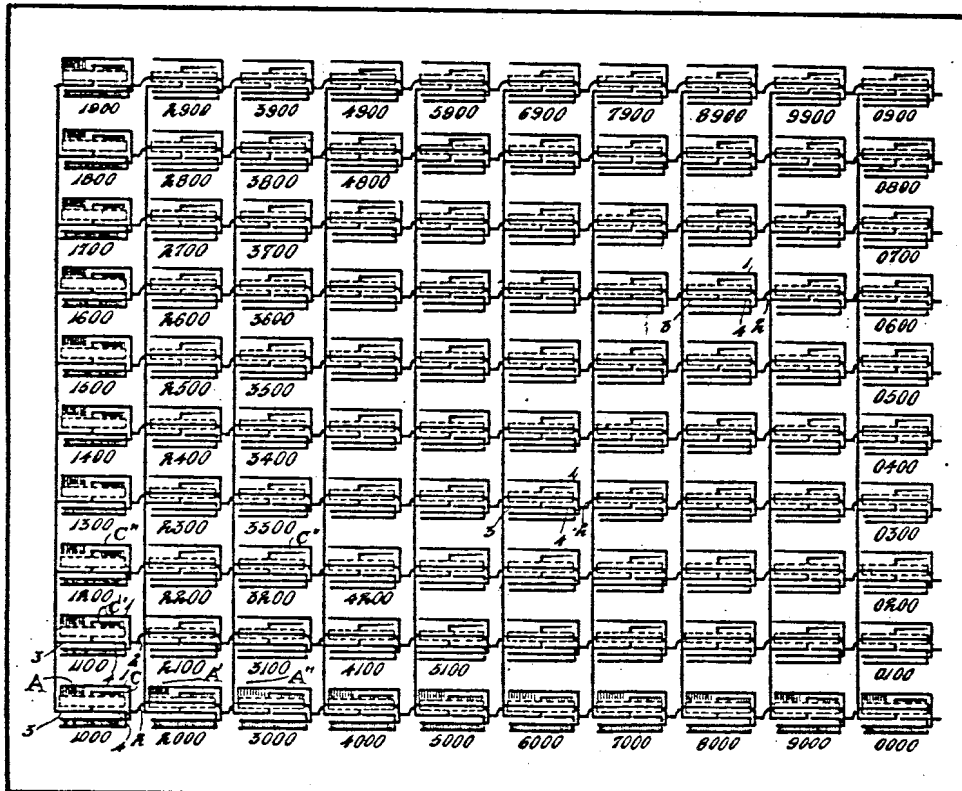


Fig. 104. Conventional Floor Plan of Automatic Exchange.

Reference to Fig. 104 will also show the manner of running the cables which are to trunk the calls. The short vertical lines at the bottom of each frame represent the 100 first selectors belonging to that hundred group. At the top of each short line is the bank of contacts for that switch. Cable 2 multiples together all these bank contacts in the first row of frames. Similarly a cable, 2, in each row, multiples together all the first selector bank contacts in all the frames of that row.

One-tenth of the wires in cable 2 end in second selectors, A, in the 1000 frame, another tenth of the wires end in second selectors, A' A', in the 2000 frame, and so on to the 0000 frame. In the cable 2 which serves the second horizontal row (frames 1100, 2100, 3100, etc.) each tenth of the wires end in second selectors in some frame of that horizontal row. This is true of all the horizontal rows.

In the same way the second selector bank contacts of each thousand are multiplied together by cables 3. Taking the left vertical row of frames (the first thousand) as an example, one-tenth of the wires in cable 3 terminate in connectors, C' C', in the 1100 frame, and so on to the 1900 frame. In each frame the banks of the connectors, C, are multiplied together and run in cable 4 to the first selectors, where they are attached to the subscriber lines leading out of the exchange to the substations. Cable 4 is called the "normal" cable.

If a subscriber in the 1000 frame desires connection with a subscriber in the 3200 frame, the former will first operate his own selector in the 1000 frame. This machine will pick out a non-busy trunk in cable 2, which ends in a second selector, A, in the 3000 frame. He will now manipulate this second selector, causing it to pick out a non-busy trunk in cable 3, leading upward and ending in a connector C', in the 3200 frame. This connector will pick out the individual subscriber in that frame.

But if the subscriber in the 3200 frame calls for any one in the 1000 frame, his path will be as follows: From his

In order to show the relations of the frames, switches, and cables more clearly Fig. 105 has been prepared. It shows a portion of four thousands, but it may be understood as extending both to the right and back so as to include the 100 frames of a ten thousand line exchange. Examine closely the frame nearest, that is, the 1000 frame A. Here the switches are each represented by a thick heavy vertical line. The bank of contacts for each is represented by the arc of a circle just below the vertical line. There are four horizontal rows of first selectors, X, each row having 25 machines. On the top shelf of the frame are the second selectors, Y, while the connectors, Z, occupy the rest of the shelf. From the banks of the first selectors cable 5 carries all the connections to a terminal strip, 6. In the next frame to the right, B, which is the 2000 frame, a similar cable carries all the first selector bank wires to the terminal strip, 8, exactly like 6. This is true of all the first selector bank cables, 5, in all the frames, so that at the upper right hand corner of each frame is a terminal strip with wires from all the first selector banks in that frame.

The first selector multiple cable, 7, runs from terminal strip 6, to terminal strip 8, multiplying all the terminals together. This cable continues on to the right from strip to strip, so that all the first selector banks in all the "naught" hundreds are multiplied together, regardless of what thousand they are in.

In the 1000 frame, A, 11 is the first selector trunk cable which taps one-tenth of the circuits in the first selector multiple cable, 7, at the terminal strip, 6. It carries these ten circuits to the second selectors, Y. These ten circuits all come from the first or bottom level of the first selector banks in frames A, B, C, etc., that is, from all the "O" frames in the various thousands. In the 2000 frame, B, another ten circuits are tapped out of the first selector multiple cable at the terminal strip, 8, and running through the first selector trunk cable end in the second selectors in that frame. These ten circuits come from the second level

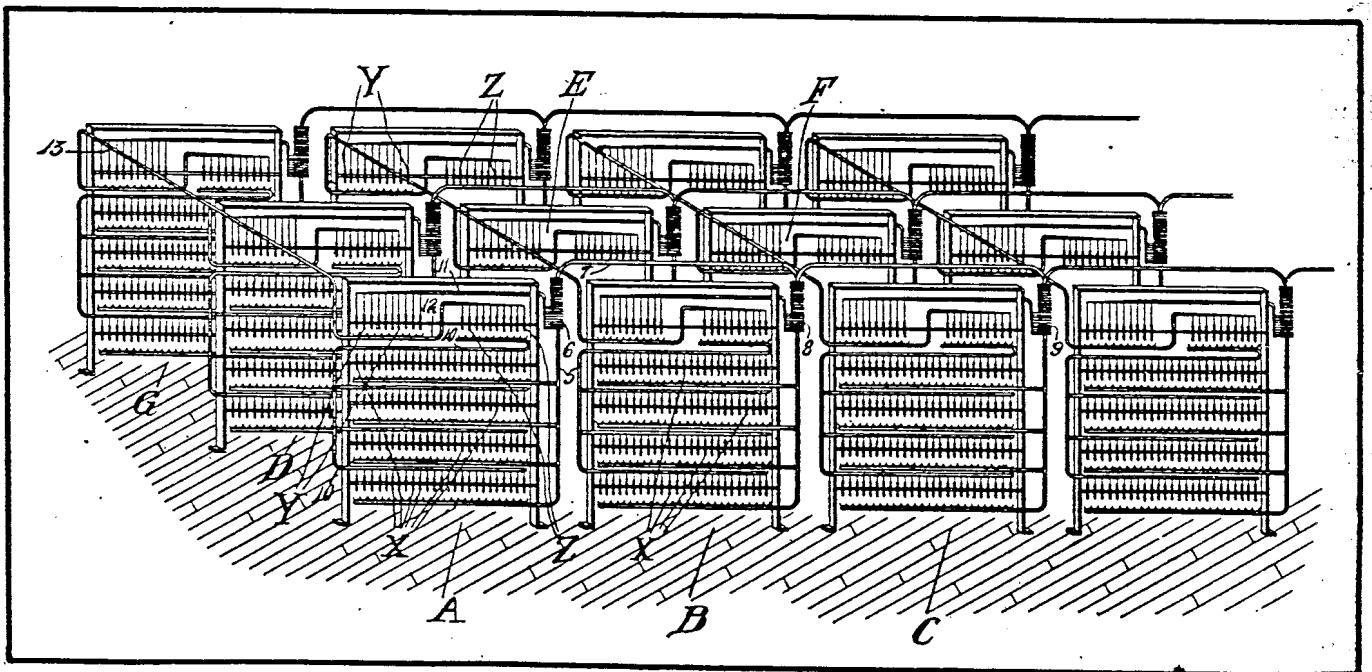


Fig. 105. Frame and Cable Arrangement.

own first selector in the 3200 frame through cable 2 to the left to a second selector in the 1200 frame, thence through cable 2 downward to a connector in the 1000 frame, from this connector to the first selector of the called line, and from there out to the substation.

in the first selector banks in frames A, B, C, etc. In a similar way the circuits coming from any level in the first selector banks terminate in second selectors in the "O" frame of the thousand which that level represents.

In the same way the first selector bank cables, first selec-

tor multiple cables, and first selector trunk cables unite all the "100" frames in the next row back, that is, *D, E, F*, etc., which are the 1100, 2100, 3100, etc., frames respectively. The same scheme of cabling holds for all the rows.

The second selector bank cables are handled in exactly the same way, though in the illustration (Fig. 105) the terminal strips are omitted. But the term "second selector bank cable" applies to the cable extending from the second selector banks to that terminal strip. The term "second selector multiple cable" means the cable which multiples together all the terminal strips in a given thousand, while the "second selector trunk cables" extend from the terminal strips to the connectors, each cable tapping off ten of the 100 circuits.

Fig. 106 shows how the bank contacts of all the first selectors in any frame are multiplied together. Each curved row of contacts, *A*, may be taken to represent a certain level in a certain first selector. Forty of these are shown, but the principle applies to the full 100. If we say that these are the first level contacts, then it will be seen that contact No. 1 of that level is wired to contact No. 1 of each and every other first selector bank in this frame. This point-for-point connecting is consistently followed through all the levels. All these wires lead into one cable, 5, which runs up to the terminal strip, 6, of Fig. 105.

All the circuits coming thus from a given level (Fig. 106) finally end in second selectors in some thousand. In each level there are ten sets of contacts, hence there are ten second selectors at the other end. This is done to give a plurality of chances of getting the desired connection. Suppose this to be the fifth level. If some person in this frame calls for a number in the fifth thousand, his vertical and rotary wipers will occupy the trunk to the first one of the ten second selectors in the fifth thousand. At the same time his private wiper will ground the corresponding contact in the private bank, thereby making it "busy."

If another person in this frame also calls for the fifth thousand, his private wiper will find the first trunk busy, and will be forced to take the second circuit, ending in the second one of the ten second selectors. A similar action occurs if several trunks are busy, the wipers being rotated automatically until a non-busy circuit is found.

As far as the calls from this frame to any given thousand are concerned, the first one of the ten second select-

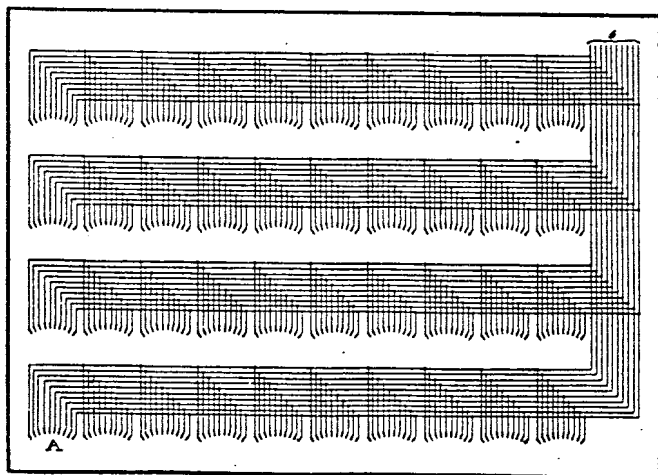


Fig. 106. Multiplying of First Selector Banks.

ors will be busy more than any of the rest, since it is always the first to be chosen. The second machine will be used less than the first one, but more than the third, fourth, etc. Finally the last ones might rarely if ever be called on for service.

This brings us up to the exact manner of connecting the first selector multiple cable, 7, Fig. 105, which runs from frame to frame, multiplying together all the banks of all the frames in a row. This cable necessarily connects like levels together, since each level corresponds to a certain

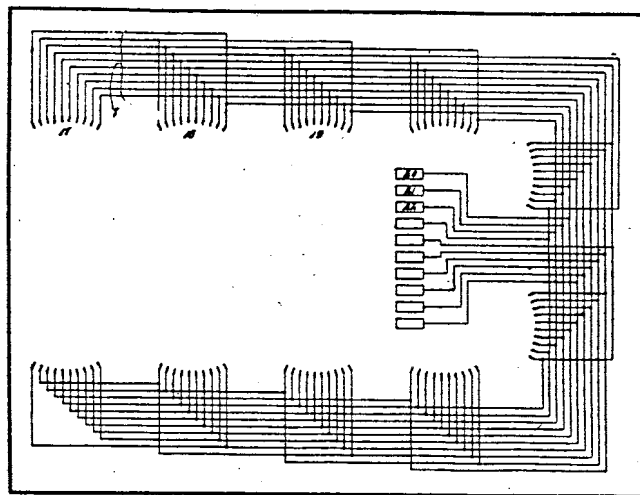


Fig. 107. Method of Rotating Connections in First Selector Multiple Cable.

thousand. If the wires from individual contacts in each level are multiplied point for point through all the frames, it will result in a very unequal distribution of the work on the second selectors. The first machine of the ten in any frame would be worked the hardest, the second a little less, and so on to the last, which would receive the least of the traffic.

To obviate this, the connections are rotated, as will be described.

In Fig. 107, let 17 represent one level of contacts in a first selector in the "0" hundred in the first thousand. Since all the first selector bank contacts in a frame are multiplied together point for point, 17 may represent a certain level in all these hundred first selectors. Also let 18 represent the corresponding level of contacts in the first selectors of the "0" hundred of the second thousand. Then 19 will be the same in the third thousand, and so on through the ten frames represented.

The ten circuits proceeding from this level and in ten second selectors, 20, 21, 22, etc. If we consider 17, 18, 19, etc., to be the first levels, then the second selectors will be located in the first thousand. In the bank 17, the first, or left hand contact will be found to run to second selector 20, which is the first machine of the group of ten. The second contact runs to the second machine, 21, the third contact to 22, and so on. In this way any call from the first thousand coming from the frame which 17 represents will have second selector 20 as its first choice, 21 as its second choice, 22 as third, etc.

But notice that bank 18 has its first contact wired to second selector 21, the second of the group. Hence any call for the first thousand coming from the frame which 18 represents will have second selector 21 as its first choice, which will not interfere with the first choice of 17. In the same way the frame which 19 represents has second selector 22 as its first choice, the rest of the bank contacts being wired to the succeeding second selectors in order.

It will be readily seen that this method of wiring secures a fairly even load on the second selectors. It also reduces the time required for a first selector to find a non-busy second selector. This automatic hunting must be done in the interval between pulls of the subscriber's dial. If the first selector is forced to hunt past eight or nine busy

points, there is danger that the subscriber may pull the next digit before the work of the first selector is done. If the next series of impulses begins to come in before the first selector has found a non-busy trunk, the first few impulses will be lost, resulting in a wrong number being obtained. If he intended to call 2749, he might get 2549, due to a change in the second digit.

This method of rotating the order of connections is applied in exactly the same way to the second selector multiple cables, in order to equalize the work of the connector switches.

30. Keith Line Switch

In all the installations described hitherto, there was one first selector for each subscriber's line. As an automatic switch is a relatively expensive affair, it will be recognized that considerable capital is tied up in selectors alone. If these switches were in use all, or nearly all of the time, we might say that the expense is justified.

Experience has proven that for manual switchboards the average maximum number of simultaneous calls in any group of subscribers will not exceed ten per cent of the number of telephones. That is, in every hundred there will be not over ten connections up. Hence, if the same ratio holds for automatic work, even during the busy hour of the day only ten first selectors will be in use. But observations have shown that the average number of connections up at any instant on an automatic switchboard rarely exceeds five per cent. This is due largely to the instantaneous release which the automatic affords. On the manual board part of the cords are tied up by connections which the operator has not had time to pull down. Also it has been noted so uniformly as to be the undoubted truth that people answer the automatic telephone more quickly than they do the manual. Accepting five per cent as the average maximum traffic, 95 per cent of the first selectors are idle even during the busy hour.

If a group of 100 subscribers could be so arranged as to use ten first selectors jointly, there would be a saving of 90 per cent in the cost of first selectors, and they form the largest single item in the central office. This 90 per cent saving is partly offset by the cost of the device which is to render the ten first selectors accessible to the 100 subscribers.

The need for such a machine was recognized early by the Automatic Electric Company, but it was not till 1904 that it was sufficiently perfected to put out into service. On Nov. 3, of that year, the Keith type line-switch was installed at Wilmington, Del. The credit for the invention of this wonderful machine belongs to Mr. E. A. Mellinger, whose skill has been displayed at many points in the development of the automatic.

The line-switch consisted essentially of 100 rows of springs. Each horizontal row contained ten sets of springs, arranged on the arc of a circle. Each set consisted of four springs and four contacts, arranged as in Fig. 108, *S* and *C*.

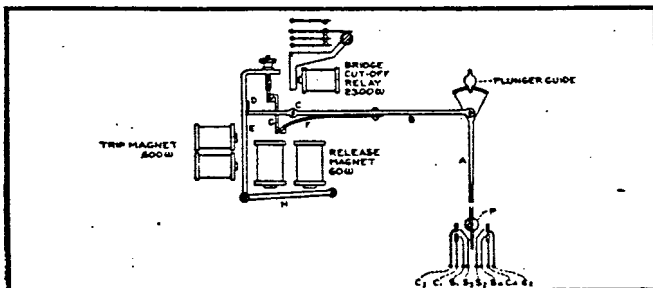


Fig. 108. Line-switch—Details of Plunger Mechanism.

The springs of a given row were multiplied together, and connected to the three magnets on a certain line. In this way the horizontal rows each corresponded to one of the subscribers' lines. In each horizontal row the first set of

contacts, *CC*, are multiplied together and lead to a first selector. The second set of contacts in all the rows lead to another first selector, and so on for the ten selectors.

A long rod, *A*, fitted with a rubber roller, *P*, is adapted to be forced in between the springs of any set, thereby forcing the springs outward till they touch their respective contacts. This connects a subscriber's line to one of the first selectors. This roller and rod, *A*, are known as the "plunger." It is carried by an arm, *B*, to the end of which it is pivoted. The fan-shaped tail of the plunger has a notch which fits over a projecting edge of the plunger guide. The latter is a vertical bar, pivoted at the top and bottom and arranged to hold all the plungers in line and opposite the sets of contacts connected to a certain first selector.

When a subscriber calls up, his own plunger is moved away from the plunger guide, and, entering the set of springs of its horizontal row, forces them apart, connecting that line to the first selector which is idle. At the same time the plunger guide is automatically moved a little, so as to point all the remaining 99 plungers at the next set of springs. If a second line now calls, it will get the next first selector, and the remaining 98 plungers will be rotated to the next first selector.

Each plunger is controlled by the lever, *B*, and the set of magnets, which are mounted on a small plate and constitute a removable unit. In Fig. 108 these magnets are shown at the left. One set of bank springs is shown, but placed edgewise, which is not their natural position. The rest of the apparatus is shown as it would appear if viewed from above. Lever *B* is pivoted to the plate at *C*, while the other end rests against a stop, *D*, on the trip magnet armature, *E*. Lever *B* has riveted to it a spring, *F*, whose free end is held by a link, *G*, the latter being attached to an adjustable screw in the end of *E*. The tension of the spring, *F*, tends to drive the plunger, *A*, into the bank, but motion is prevented by the stop, *D*. But when the trip magnet is energized, in attracting its armature, *E*, it removes the stop, *D*, from lever *B*. The latter then, driven by the spring, forces the plunger, into the set of springs opposite which it has been standing.

The trip magnet armature, *E*, is pivoted to the free end of the release magnet armature, *H*. When the release magnet is energized and pulls up, stop *D* is moved beyond the end of lever *B*, so that when the release magnet falls back the pressure of the spring, *F*, withdraws the plunger from the set of springs in the line-switch bank.

The mechanical arrangement of spring *F*, whereby it is made to produce these two opposite motions, is quite interesting and worthy of notice. The natural tendency of the spring is away from the pivot *C*, to bend itself still more than shown in the figure. The motion which it produces will always be that which is necessary to increase the distance between its free end and the lever *B*. Link *G* transmits the force of the spring to the armature *E*, and by stop *D* this force is exerted on the left end of lever *B* to which the spring, *F*, is itself attached. Thus we have a force acting with a tendency to produce rotation in one direction at the free end of *F*, and the same force tending to cause rotation in the opposite direction at *D*. Since the lever arm from *C* to *D* is longer than from *C* to *G*, the

moment of the former will be greater, and the lever *B* will be forced back against the plunger guide. This motion allows spring *F* to follow its tendency to curl away from lever *B*.

When stop *D* is removed from contact with the left end of *B* the conditions are changed. Armature *E*, against

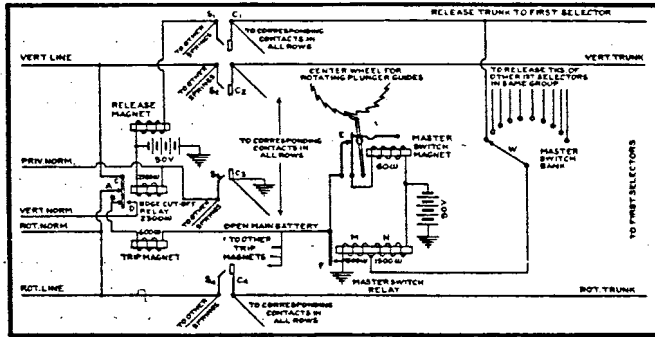


Fig. 109. Line-switch, as installed at Wilmington, Del.

which the spring *F* is pulling can not move any farther, being against a stop. Hence the only motion which will allow the spring to curl away from lever *B* is for the left end to move back, driving the right end forward, carrying the plunger into the springs of the bank.

The plunger guide (which by its position determines which first selector shall be used by the next line to call up, is under the control of a motor magnet. This motor magnet, known as the "master switch magnet," acts, through a ratchet, on a center wheel on which are cams operating a lever attached to the plunger guide. In practice the 100 line units (of Fig. 108) are divided into four groups of 25 plates each. Each group of 25 has its own guide bar, controlled by the center wheel. As the center wheel revolves it moves all four plunger guides in exact synchronism, keeping all the idle plungers pointed at the same sets of bank springs.

A simplified diagram of the circuits of the master switch and one of the line units is shown in Fig. 109. *C*₁, *S*₂, *S*₃, and *S*₄, are one set of springs and are adapted to touch the contacts *C*₁, *C*₂, *C*₃, and *C*₄, respectively. The springs are multiplied to all the other springs in the same horizontal row and represent a certain line. The contacts are multiplied to corresponding contacts in all the rows, and represent a certain first selector. When the plunger operates in this position, the four springs shown make contact with the four contacts shown.

The vertical and rotary lines coming from the left are the subscriber's wires from the substation. They are normally short-circuited by the main spring *C* and one back contact, *A*, of the bridge cut-off relay, both being connected through *B* with the trip magnet and negative (main) battery. Thus, a ground on either line will cause the trip magnet to operate.

The master switch magnet has attached to its armature a pawl which acts on the center wheel. It moves the latter on release, not on pulling up. The master switch magnet is controlled by the master switch relay, whose winding is in two parts. Each winding is of 1,500 ohms resistance, and the two are connected in opposition, so that although normally there is current flowing, the armature is not attracted.

Attached to the plunger guide is a wiper, *W*, which moves over the master switch bank. Each point of the latter is tapped onto the release trunk of one of the first selectors. The position of the wiper corresponds to that of all the idle plungers.

The first selector circuit which works with the line-switch is given in Fig. 110. The general arrangement of

relays and magnets is the same as has been described before, and merits no special comment. The special features introduced by the line-switch are as follows: The release trunk coming from the line-switch bank runs to a contact, *C*, on the release magnet. This contact is operated momentarily by the back kick of the armature when the release magnet is de-energized. The off normal relay (5,500 ohms) is also attached to the release trunk, and to the first contact of side-switch 4. The off normal relay controls the individual off normal lamp.

The operation of the apparatus will now be described. The substation dial is arranged to give a preliminary impulse on the rotary wire during the pulling of the dial for the first digit. This allows current to flow from ground over the rotary wire to contacts *A* and *B* of the bridge cut-off relay, Fig. 109, through the trip magnet, contact *E*, and the master switch magnet to negative battery. This energizes the trip magnet, but not the master switch magnet, on account of the low resistance (60 ohms) of the latter. The action of the trip magnet lets the plunger fly into the set of springs, *S*₁, *S*₂, etc., forcing them against their respective contacts.

At *S*₂ and *S*₄ the vertical and rotary lines are connected straight through to the first selector. At *S*₂ the bridge cut-off relay is grounded and energized, disconnecting the trip magnet at *B*, taking the short circuit off the lines at *A*, and connecting up the vertical normal at *D*. At *S*₃ the release is connected to the release trunk leading to the first selector. This last act places the release magnet (60 ohms) as a shunt around the winding *N* of the master switch relay, since the master switch wiper, *W*, is resting on this release trunk. This practically short-circuits the *N* winding, whereupon the *M* winding becomes effective and pulls up the armature, closing contact *F*. The master switch magnet now pulls up until its pawl catches the next tooth on the center wheel. Just then contact *E* breaks, cutting off the current, and a spring forces the armature back, carrying with it the pawl and center wheel. By this means the plunger guide is made to move all the idle plungers one notch over, so that each is opposite the next first selector. The master switch wiper, *W*, partakes of this motion and now rests on the next contact to the right, which is tapped onto the release line of the first selector which will be used next.

When the line switch tripped in on the first selector, the release magnet of the former became connected to the release trunk of the latter and fed negative battery to it. In Fig. 110 it will be seen that this caused current to flow

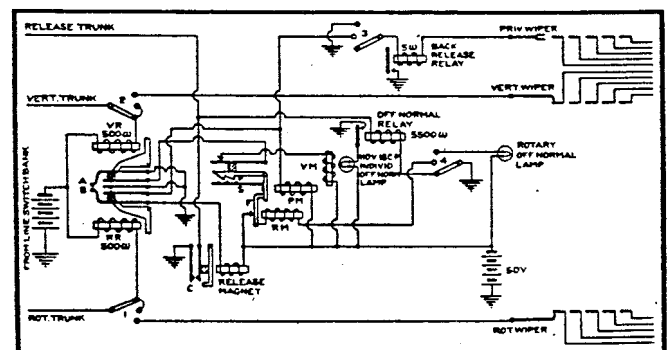


Fig. 110. First Selector to Work with Line-switch, Wilmington.

through the off normal relay, pulling it up. On account of its high resistance (5,500 ohms) it prevented the release magnet of the line-switch from energizing. The off normal relay caused the individual off normal lamp to light. If for any reason the apparatus failed to work, this light would continue to burn, calling the attention of the attend-

31. The sub-office

ant. But if the call proceeds as it should, the lamp will almost immediately go out and the rotary off normal lamp light instead.

It will be observed that the line-switch adds no impediment to the talking or signaling circuit, the vertical and rotary lines through it being clear of all attachments. The third wire (release trunk) takes care of the auxiliary functions.

In releasing, the vertical and rotary line wires are grounded at the substation in the standard manner. This causes the connector to release itself and also to feed current back over the release trunk to release the second selector, as has been previously described. In turn, the second selector feeds battery back over the release trunk to the back release relay of the first selector, Fig. 110, pulling it up. This energizes the release magnet, which, when released, momentarily closes contact C, sending an impulse to the release magnet of the line-switch, Fig. 109, releasing the latter. The plunger being withdrawn from the bank springs rests against the plunger guide till the latter has rotated far enough to allow the notch on the fan-shaped tail, Fig. 108, to fit over the edge of the plunger guide.

Fig. 111 shows the change made in a single 100 group by the use of the line-switch. The space inside the broken line would, on the old system, be filled with 100 first selectors. These are now replaced by the line-switch and ten first selectors. There is a great reduction in the space required in an exchange.

The cost of a telephone plant may be divided into three classes:

1. Cost of apparatus.
2. Cost of land and buildings.
3. Cost of wire plant.

The last is the largest item. It may be from half to two-thirds of the total cost of the exchange. Losses in it are to be carefully watched. If by any device its cost can be reduced, it should be provided.

Suppose we have 100 subscribers living three miles from a central office, from which they are supplied with telephone service. To give them satisfactory service will require 100 circuits three miles long. During the greater portion of the day these lines are idle, and even at the busy hour perhaps only ten of them may be in use at any one time, the other 90 being unused. To prevent this waste of unused property party lines have been proposed. They are at best a poor remedy. If we put a sufficient number

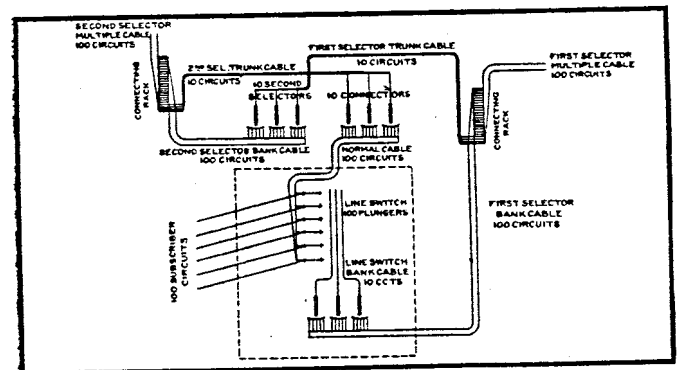


Fig. 111. Cabling and Arrangement of Line-switch in a 100 Frame.

of stations on each circuit to secure the desired wire plant economy, the service will be intolerably bad. On the other hand, if we limit the number of stations per circuit to the number which will give first-class service, the economy of wire is lost. There is only one thing to do, limit the number of circuits serving our 100 subscriber group to that

required by the busy hour traffic and make each of the circuits available to all the subscribers.

With the manual system, the only way to accomplish this end is to place a branch switchboard at the center of the 100 substations, with an operator to trunk the calls to the main office. But the fixed charges of rental, operator's wages, light, heat, etc., make this more expensive than to extend the whole 100 circuits to the main office. Clearly, some mechanical device for switching is the only way to work economy in this direction if dealing with small groups.

A close examination of Fig. 111 will show how a beginning was made in this direction by the invention of the line-switch. It will be seen that the line-switch bank cable and the second selector trunk cable each contain ten circuits. It is therefore possible to remove the line-switch and the ten connectors from the main office and install them in the center of the 100 substations, connecting them to the main office by 30 wires. This is actually what was done, for the first time at Dayton, Ohio, and it proved to be a very great success.

32. Party Lines

One of the attempts of telephone engineers to economize wire was the introduction of the party line. The saving was partly offset by the more complicated and costly apparatus required for selective ringing, yet the party line proved a money-maker and spread rapidly all over the country. The automatic system was built up on the idea

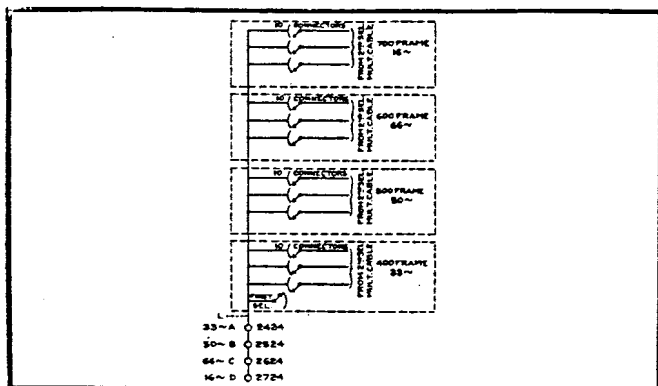


Fig. 112. Outline of Scheme for Ringing Party Lines.

of individual lines, that is, one subscriber per line. Naturally the objection was urged against the new system that it could not supply party line service. Though aiming at another end, it was necessary to meet this demand, and supply it until something better should be forthcoming.

In the main, two problems confronted the engineers. The first was the selective ringing of the called station without special manipulations on the part of the user. The second was to ring back on the same line that originated the call. The Thompson and Robes system, employing biased bells, two from each wire to ground, could not be used, since both wires must be clear for operating the switches. The harmonic system, which was developed by Mr. W. W. Dean, was the only one adapted to the purpose, being free from grounds at all times. Hence it was adopted.

The manner of allowing the calling subscriber to determine which frequency of ringing current shall be turned onto the called line is simple and interesting. Referring to Fig. 112, let the four rectangles represent four of the frames of an exchange, each frame holding apparatus for serving 100 subscribers' lines. We may suppose them to be in the second thousand. The connectors alone are represented, three of each being shown. The line *L* represents the line circuit, on which are four telephones. The four bells differ from each other in that they are tuned to ring on the frequencies set down opposite them. The first station, *A*, rings on 33 cycle current, *B* on 50, *C* on 66, and *D* on 16.

In the office the line *L* is multiplied to the banks of all the connectors. Let us suppose that this line has 24 for its last two digits. It will then be wired to bank contacts 24 in each of the ten connectors in the 400 frame as shown. The same line is also multiplied to contacts 24 of each connector in the 500, 600, and 700 frames.

The ringing relays of all the connectors in the 400 frame are wired with 33 cycle current, while the relays of the 500, 600, and 700 frames are supplied with 50, 66, and 16

cycle ringing current respectively. The result of this arrangement is that if any telephone in the exchange calls "2424", the switches will act as follows: The first digit will step his first selector up two notches and select a non-busy trunk to the second thousand in which the desired line ends. The next digit, 4, will trunk the connection to one of the connectors in the 400 frame. The last two digits, 2 and 4, will lift and rotate the wipers of this connector till they rest on contact 24. On pressing the ringing button the relay will send out on the called line, *L*, the only current with which it is supplied, 33 cycle. This current will pass through all the bells on the line, but will ring only the one at *A*, which is tuned to that frequency.

But if the number 2524 had been pulled on the dial, the call would have been directed into the 500 frame and would have ended on contact 24 of one of the ten connectors belonging to that frame. It thus gets to the same line, *L*. Since all these connectors are supplied with 50 cycle current, the act of ringing will send out that frequency, ringing the bell at *B*. It is perfectly obvious that station *C* may be called by the number 2624 and station *D* by 2724. To place the numbers in a form more easily remembered, they have been tabulated as follows:

Station on Line.	Call Number.
A	2424
B	2524
C	2624
D	2724

It is the "hundreds" digit which fixes the station called. By this arrangement the calling subscriber need not know that he is calling a party line, for the call number will have nothing about it to mark it as different from "straight" or "special" individual lines.

For calls proceeding from any station on the party line, one first selector is provided as indicated. In the same way 99 other 4-party lines are wired up in the four frames. Each of the frames will have the full number of second selectors and connectors, but only 100 first selectors are required. The 100 party lines thus handled occupy as many call numbers as if all the 400 stations were on individual

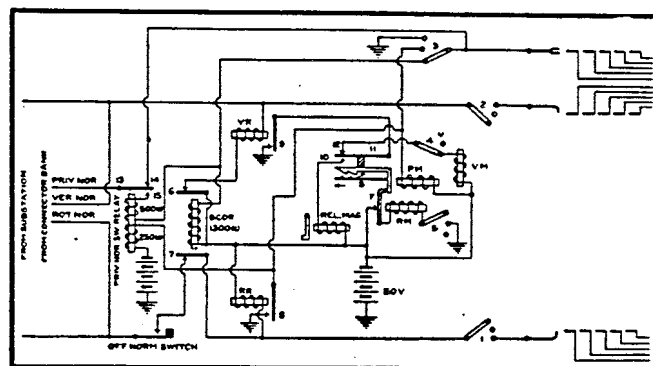


Fig. 113. First Selector for Party Line. First Installed at Miamisburg, Ohio.

lines. But it will be noted that there is a saving of 300 first selectors and 300 line circuits in the wire plant.

THE REVERTING CALL.

Suppose that a person desires to call a station on his own line. He will pull the first digit calling for his own thousand, for example, 2. A ground is thus placed on his

own private wire which is multiplied to contact 24 of each of the connectors in the four frames. Any call coming in through them will strike this ground, release the connector and give the busy tone. His next pull will trunk him to one of these connectors corresponding to the frequency of the desired station. When he pulls the last two digits, he will be connected to his own line, but this has been made busy by the act of calling, so that the call cannot be completed.

The problem was to devise a plan whereby this ground could be momentarily taken off the private normal, to allow the connector to get in if the call came back to its own line. The means are shown in Fig. 113. This is a bridging first selector such as was installed at Miamisburg, Ohio, June, 1905. It was a 1,000 system, and therefore had only first selectors and connectors. The vertical and rotary lines from the substation come in at the left. The vertical line normally goes through the vertical relay to negative battery, which it gets through contact 6 of the bridge cut-off relay. The rotary line is open at the off normal switch, but if the latter be closed connection is had to negative battery through contact 7 of the bridge cut-off relay and winding of the rotary relay. The rotary relay contact, 8, controls the private magnet as usual. The vertical relay controls the vertical magnet, but if the private magnet be energized it will ground the release magnet through contact 10 of the private magnet.

The bridge cut-off relay is used to cut battery off the line when receiving a call, and is wired from negative battery to the first contact of side-switch 3.

The real innovation consists in the addition of a private normal switching relay, which handles the private normal wire in the manner which will be described. Its armature, or main spring, 13, is wired directly to the private normal, which it connects through back contact 14 to the private wiper. The front contact, 15, is connected through a 500 ohm winding to the end of the bridge cut-off relay which goes to side-switch 3. The 250 ohm winding runs from negative battery to main spring 8 of the rotary relay, so that it is under the control of the latter, as is similarly the private magnet. Every time the rotary relay energizes it pulls up simultaneously the private magnet and the private normal switching relay, since they are in parallel.

The connector, Fig. 114, differs little from the bridging type which has been described before, but the changes are very important for the operation of party lines. The rotary relay carries an extra spring and contact, which are looped into the release magnet circuit. The release magnet is made to release the connector switch on pulling up, not on falling back, as in other switches. On the wiper

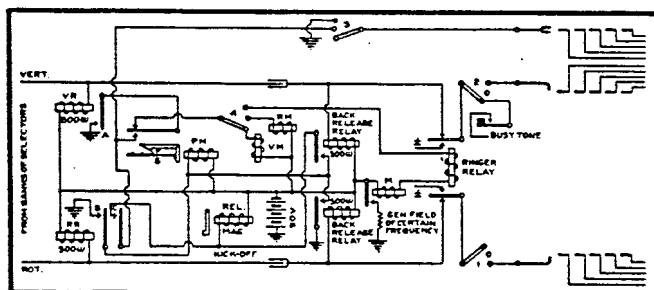


Fig. 114. The Miamisburg Type of Connector for Bridging Party Line.

side of the condensers are bridged the two back release relays, each 500 ohms, so that the called subscriber can release if necessary.

The ringing current is furnished by a motor-generator set consisting of a motor direct connected to four a. c. ringing generators. These give the four frequencies for

harmonic ringing. The fields of these generators are normally unexcited. The ringing relay of the connector has a special relay, *M*, cut in series with it. This relay *M* controls the field current for the generator giving the particular frequency which this connector uses. Thus, when the ringing relay is energized, the relay *M* simultaneously excites the field of the generator.

The private magnet is peculiar in that the second upper

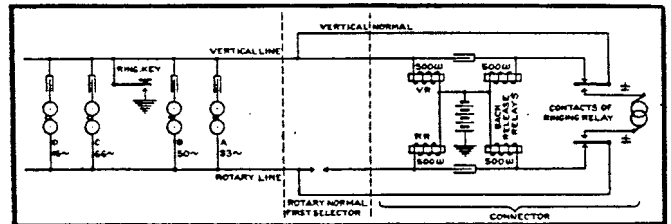


Fig. 115. Condition While a Reverting Call Is Being Made.

tooth is cut off, leaving only one. The effect of this change will appear in the discussion of operation which follows.

If a station on a party line calls some one on another line, the operation of both first selector and connector is essentially the same as any bridging system. But if it be a reverting call, coming back to a station on its own line, the action is as follows: The description must make free use of both Figs. 113 and 114, and in the rapid changes from one to the other the reader will be obliged to follow the diagrams with care.

When the first digit has been pulled, the off normal switch in the first selector, Fig. 113, is closed, giving a connection through that switch over the vertical and rotary lines, with the vertical and rotary relays bridged across, negative battery being tapped on at the center.

On pulling the second digit the vertical relay in the connector, Fig. 114, operates the vertical magnet through side-switch 4, stepping the wiper shaft up. The following ground on the rotary line energizes the rotary relay, which pulls up the private magnet. On falling back, the private magnet lets the end of the side-switch lever, *S*, slip to the second lower notch, thereby moving all the side-switch members to their second positions. At 1 and 2 this does nothing. At 3 the private wiper is connected to contact *C* of the rotary relay. At 4 the control of the vertical relay is switched to the rotary magnet.

The last digit pulled sends a series of impulses on the vertical line, operating the vertical relay, which in turn operates the rotary magnet through side-switch 4. This rotates the wipers to the called line, which in this case is the same as the calling. At the end of the series of impulses on the vertical and before the impulse on the rotary, the wipers of the connector, Fig. 114, are resting on the normal wires of the first selector, Fig. 113. The vertical wiper is on the vertical normal, rotary wiper on the rotary normal, and private wiper on private normal.

Now, when the last impulse comes in on the rotary line, the rotary relays in both first selector and connector will be pulled up simultaneously. In the first selector, Fig. 113, the rotary relay will energize the private magnet and the private normal switching relay at once. The latter switches the private normal from ground at side-switch 3 to negative battery through the bridge cut-off relay. In the connector, Fig. 114, the rotary relay closes contacts *B* and *C*. Contact *C* connects the release magnet to the private wiper to test the private wiper, but since the private normal switching relay of the first selector has removed ground from it, nothing will happen. Contact *B* will cause the private magnet in the connector, Fig. 114, to pull up. Since the second upper tooth has been cut away, the side-switch will immediately snap into its third position.

At 1 and 2 the line will be connected through. At 3 the private wiper is grounded. This causes current to flow from ground through side-switch 3, private wiper, over the private normal to the first selector, Fig. 113, through the contacts 13 and 15 of the private normal switching relay, through its 500 ohm winding, through the 1,300 ohm coil

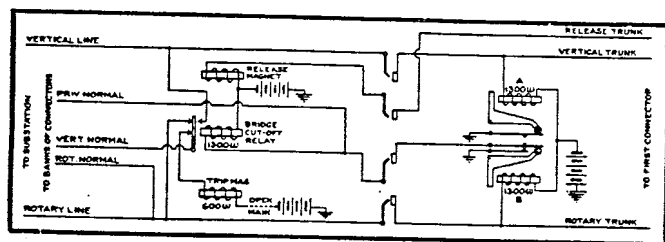


Fig. 116. Grand Rapids Party Line Switch.

of the bridge cut-off relay, to negative battery. Thus the private normal switching relay is locked up, and the bridge cut-off relay pulled up, cutting off the vertical and rotary relays from the line.

At 4, Fig. 114, the vertical relay control is switched to the ringing relay. Now, when the calling subscriber presses his ringing key, he grounds the vertical wire. This pulls up the vertical relay in the connector, energizing the ringing generator, and the former connects ringing current to the vertical and rotary wipers. It flows over the vertical and rotary normals, Fig. 113, in the first selector, to the line where it rings the one of the four bells which is in tune with it. Fig. 115 shows schematically the connections which are important during talking and ringing. The rotary line is broken in the first selector, while the vertical is continued through. But this does not unbalance the line, since the rotary is in connection at the wipers of the connector.

Since there are no relays connected to the line in the first selector it would seem impossible to release. But when the descending hook grounds both vertical and rotary lines, the two back release relays in the connector operate the release magnet, which kicks the wipers back to normal on the pull-up. Hence the connector will be reset while the ground is yet on both wires. The removal of the ground from the private normal lets the bridge cut-off relay in the first selector fall back, reconnecting both vertical and rotary relays in that switch. They immediately pull up, energize their release magnet, and complete the release of the connection.

PARTY LINES AND LINE-SWITCH.

At Grand Rapids, Mich., the party line was required to operate through local battery line-switches. Hence the removal of the ground from the private normal during the reverting busy test had to be performed at the line switch instead of the first selector. This was done by bridging two 1,300 ohm relays across the line as shown in Fig. 116. Relay *B* is the private normal switching relay, but it merely removes the ground while the connector is making the test. The ground is then restored, which pulls up the bridge cut-off relay again so that the vertical normal will be connected to the vertical line. During the act of releasing both *A* and *B* pull up. Relay *A* restores the ground on the bridge cut-off relay which *B* removes, thus preventing the trip magnet from being affected.

33. South Bend and Common Battery

Up to this time (1904-5) the automatic system used dry cells in the substation instruments for talking purposes. There was a valid objection to this, since common battery working had demonstrated its superior qualities, and was demanded by progressive exchanges. Hence the automatic was rearranged to

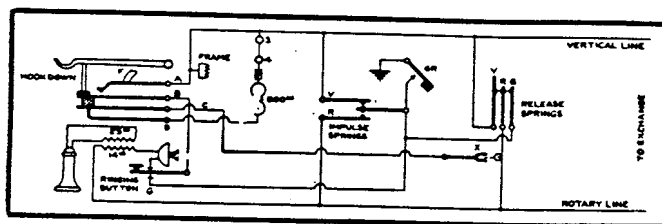


Fig. 117. Circuit of Common Battery Wall Telephone, South Bend.

meet the need. The first plant to operate on this system was at South Bend, Ind., which was installed in May, 1905.

This installation was required to operate jointly with a manual board, both being in the same building. Calls originating from manual subscribers had to be completed manually by plugging into jacks connected to the lines of the automatic subscribers. The automatic subscribers also had to be able to complete their calls without an operator, using special connectors wired to the lines of the manual subscribers. The manual board was a Kellogg common battery 2-wire multiple.

The revised substation circuit is shown in Fig. 117. In its normal condition, hook down, the 500-ohm. bell and 2 M. F. condenser were alone across the line. The ground spring, *Gr.*, is let down by the first turn of the dial, furnishing ground for the impulse springs, ringing button, and release springs. On the hook, finger *F* from the dial forms the stop for the top spring *A*. When the hook is up, *A* and *B* close the talking circuit. During the dial movement finger *F C* is lifted, opening the contacts *A-B*, thus separating the vertical and rotary lines while the impulses are going in. The talking set consists of an induction coil with primary in series with the transmitter, the receiver being wired to the secondary winding.

The first selector is shown in Fig. 118. The vertical and rotary lines from the substation normally pass through side-switches 1 and 2, contacts 6 and 7 of the bridge cut-off relay, vertical and rotary relays, to negative battery. The vertical relay controls the vertical magnet, or release magnet, as determined by the private magnet. The rotary relay controls the rotary magnet and the private magnet in rotating to find a non-busy trunk, the former having an individual interrupter. The off normal switch is restricted to lighting the off normal lamp while the vertical impulses are coming in, going out as soon as rotation begins.

All the steps of calling, except the last, are exactly like those of the trunk release first selector previously described, and need not be again described. When the non-busy trunk has been found, and the side-switch slips into the third position, member 3 becomes grounded to protect the trunk line. The private normal wire, being tied to side-switch 3, shares its ground to protect from calls to this line from other stations. In addition, the line jack on the manual board must be made busy, so that the operators will not put up a connection.

On the Kellogg board the sleeve of the jack is at ground

potential when the line is free, but has some battery when busy. Hence side-switch 5 is arranged to connect the private normal grounding relay through the bridge cut-off relay to battery. This gives the sleeve of jack the desired busy test condition.

If a call comes for this line from another automatic subscriber, it comes through connectors and over the normal wires. When the side-switch of the connector slips into the third position, it grounds the private normal. This pulls up the bridge cut-off relay, cutting off the vertical and rotary relays of the first selector. The vertical wiper of the connector carries negative battery, which is fed through side-switch 2 and contact 8 of the bridge cut-off relay to the sleeve of the manual jack. This makes the latter busy.

When a connection is put up from a manual to an automatic subscriber, the operator plugs into the line jack of the latter with the standard Kellogg cord. The tip carries positive or ground battery through the 100 ohm supervisory relay. The sleeve carries negative battery through the 100 ohm control relay. This latter pulls up the private normal grounding relay of the first selector, thereby grounding the private normal and operating the bridge cut-off relay. The former protects the connection, the latter switches the jack to the automatic subscriber's line, giving a clear circuit over which to ring.

The second selector, Fig. 119, is novel in that it has no side-switch. Its place is taken by the line switching relay, the cam switch, and certain functions of the private magnet. The battery supply of the vertical and rotary magnets and the private magnet is controlled by a back contact on the release magnet. The vertical magnet is controlled by the vertical relay, and the private magnet by the rotary relay, as usual. But the front contact, 1, of the private magnet, connects the latter through the release relay to the private wiper for testing the lines in finding a non-busy trunk.

The release trunk from the first selector bank goes through contacts *A* and *B* (open), the contact of the release relay being in parallel, to the release magnet and battery. Normally the cam switch on the wiper shaft holds the line switching relay connected to the release trunk. Therefore, when a first se-

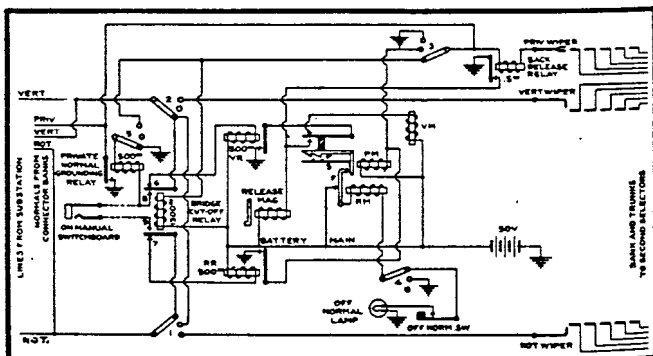


Fig. 118. Common Battery First Selector, as Installed at South Bend.

lector becomes connected to this second selector, and grounds the release trunk, the line switching relay is pulled up, connecting the vertical and rotary relays to the line.

Now, as the vertical impulses come in, the vertical magnet steps the wipers up to the desired level. The single rotary impulse pulls up the rotary relay, and through it the private magnet. Instantly the rotary magnet, getting ground through 2 and 3 of the private magnet, pulls up, rotating the wipers to the first trunk. The finger, *F*, of the rotary magnet presses the armature of the private magnet to the right, closing contact 1. If this first trunk is busy, the private wiper will find ground, so that the private magnet will be held up, though the release relay will not. The rotary relay may now fall back, for the succeeding operations are beyond its control.

This first rotary motion caused the cam switch to move to the right, so that the line switching relay is changed from the release trunk to spring 2 of the private magnet. It is now held up through contact 2-3 while the non-busy trunk is being found.

The rotary magnet having broken its own circuit by the contact at *F*, falls back and catches a new notch on the ratchet cylinder. Contact *F* closes, causing it to pull up, rotating the wipers to the next trunk, finger *F* holding contact 1 of the private magnet closed while the private wiper slips from one contact to the next. When a non-busy trunk is finally found, the lack of ground on the private wiper lets the private magnet fall back, which cuts off both rotary magnet and line switching relay. The latter cuts off the line relays and cuts the line through to the wipers. The private wiper has ground put on it by contact 4 of the private magnet.

The ordinary connector, Fig. 120, for calling automatic subscribers, differs materially from connectors previously described, for it is here that the changes are made to enable the feeding of common battery for talking. The vertical and rotary relays, each of 400 ohms resistance, are in series with the two windings of the differential relay, *DR*. The two coils of the latter are connected so as to aid each other normally. The vertical line is tied permanently to negative battery. The rotary line, through the rotary and differential relays, goes to spring 6 of relay *CR*, where it normally gets negative battery. But relay *CR* may switch it to side-switch 3, where later it may get ground or positive battery. The differential relay, *DR*, controls the battery feed to delay *CV* on its back contact, and the release magnet and ringing relay on its front contact.

Taken in detail, the operation is as follows: The impulses for the tens digit come in over the vertical line, pulling up simultaneously the vertical and differential relays. The latter does nothing. The vertical relay grounds its spring, 7, and through the private magnet contact 9 and side-switch 4 operates the vertical magnet, stepping the wipers up to the desired level. Now comes one impulse on the rotary line, pulling up the rotary and differential relays. The latter again does nothing. The rotary relay pulls up the private magnet, and, on releasing, lets the side-switch slip to its second position. At 1

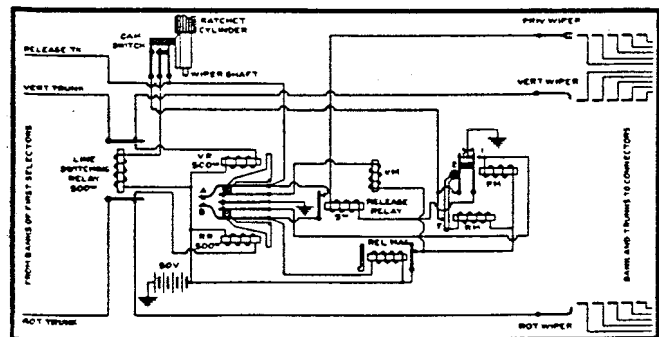


Fig. 119. Second Selector Without Side-Switch, South Bend.

and 2 nothing happens. At 3 the private wiper is connected to contact 10 of the private magnet. At 4 the spring 7 of the vertical relay is switched to the rotary magnet.

On the last, or units pull of the dial, the impulses over the vertical line now operate the vertical relay and rotary magnet, moving the wipers around to the called line. The last impulse is on the rotary line, pulling up the rotary relay and the private magnet. If the called line is busy, the private wiper will be resting on ground. Hence, closing contact 10 on the private magnet will release the connector. The calling subscriber, on ringing, grounds the vertical line, stepping the shaft up one or two notches. This closes the off normal switch, putting on the busy tone.

But if the called line is not busy, the motion of the private magnet lets the side-switch snap into the third position. At 1

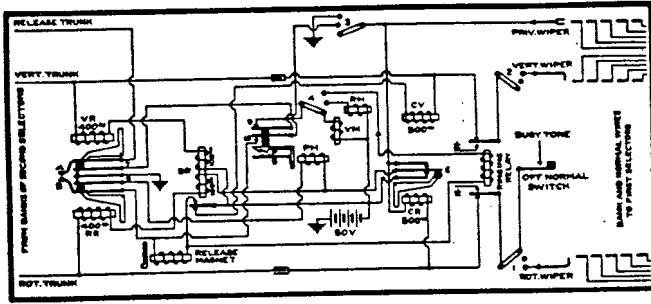


Fig. 120. Common Battery Connector, South Bend.

and 2 the lines are connected through to the called line. At 3 ground is placed on the private wiper to protect from intrusion. This also pulls up the bridge cut-off relay of the first selector of the called line (see Fig. 118), cutting off the circuits of that switch and putting the busy condition on the line jack on the manual board. At side-switch 4 (Fig. 120), vertical relay spring 7 is switched to the ringing relay.

To ring, the calling subscriber presses the ringing button (see Fig. 117), grounding the vertical line. This pulls up the vertical and differential relays (Fig. 120). The former supplies ground, and the latter battery, to the ringing relay, which sends ringing current out on the called line.

Up to this time we have had negative battery connected to both wires of the calling subscriber. This may be called "selecting condition" or "selecting battery." It leaves the talking set dead. By some means one of the two wires must be switched to positive battery, so that a flow of current will result through the calling subscriber's transmitter and coil for talking purposes. This is done by the answering of the called subscriber. Relay *CR* now feeds positive battery to the rotary line and *CV* negative battery to the vertical line of the latter. Owing to the condenser in series with the bell, no current flows. But when the subscriber answers, current flows through *CR* and back through *CV*. *CR* pulls up, switching the rotary line of the calling station from negative to positive battery, so that the latter can talk.

Conversation is now carried on under the conditions found in most independent cord circuits, employing the condenser-retardation coil system. The circuit is clear of all other bridges. Each transmitter is fed through 500 ohms impedance on each side of the line. The differential relay does not pull up during conversation, since the two windings oppose each other. Contact *AB* is closed, but nothing happens since the release magnet has no battery, the front contact of *DR* being open.

There are two conditions in releasing. In the first, assume that the called subscriber has hung up. Relay *CR* has fallen back, restoring negative battery to the rotary line through differential and rotary relays. When the calling subscriber hangs up, he momentarily grounds both line wires and then clears them. This pulls up the vertical, rotary and differential relays. The latter feeds negative battery to the release magnet. The vertical and rotary relays close contact *AB* and feed this current from the release magnet over the release trunk to the release relay of the second selector (Fig. 119) and to ground. From here the release is carried on to the first selector over the release trunk as has been described before.

In the second condition, consider the called subscriber to be still on the line. Relay *CR* is still pulled up. This leaves positive battery on the rotary line, in which case short-circuiting the calling line will not pull up the differential relay. But as the hook goes down it grounds both lines. This places a short circuit through earth on the rotary relay and the lower coil of the differential relay. Hence the upper coil becomes effective,

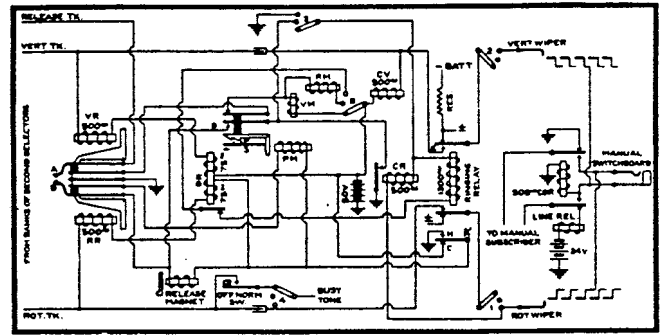


Fig. 121. Common Battery Connector to call Manual Subscriber, South Bend.

the armature pulls up, cutting off negative battery from the called line. This lets *CR* fall back, restoring negative battery to the lower coil of the differential relay and rotary line. The rotary relay now comes up, closing *AB* and the release proceeds as usual. The called subscriber cannot release.

The special connector for calling manual subscribers is shown in Fig. 121, and possesses a number of unusual features due to the 2-wire jack of the Kellogg board. There is no private wiper, the busy test being made by the rotary wiper, relay *CR* and the release magnet all in series. This occurs at the instant the rotary line is grounded at the end of the last digit. Side-switch 3 is in the middle position and the private magnet pulled up. If the called line is free, the rotary wiper rests on an open point. If it is busy, there will be ground on the tip of the jack (which is the rotary bank point) due to the supervisory relay of the operator's cord circuit, or relay *CR* of some other connector. This ground causes current to flow from negative battery through contact *C* of the ringing relay, release magnet, contact *D* of the private magnet, side-switch 3, relay *CR*, rotary wiper, to manual board and ground. Relay *CR* pulls up, putting a "dead" ground on the release magnet, which returns the connector to its normal position. As usual, the busy tone comes through the off normal switch on ringing.

When connection has been made to the called line, the ringing relay is held up continuously by positive battery from side-switch 3 and negative battery through the contact of the differential relay *DR* and side-switch 5. It is the ringing relay which connects positive battery to the rotary side of the calling line for talking purposes, springs *H* and *K* performing the function. Negative battery causes current to flow through relay *CV*, contact *E* of ringing relay, and vertical wiper to hold up the cut-off relay of the manual line.

When the ringing button of the calling station is pressed, the vertical and differential relays pull up. The latter opens the circuit of the ringing relay which falls back, cutting off the switch circuit and projecting ringing current over the called line. While ringing, a tap to negative battery through resistance holds up the cut-off relay in manual board.

It will be noted, by reference to Figs. 118 and 119, that when a selector has completed its work the lines are cleared of apparatus. Release must come over the release line and private wiper. In every exchange there are one or more levels in the selector banks which are not in use. These are termed "dead levels," and if by mistake a subscriber gets in on one of these he will be unable to release. To obviate this trouble the release for dead levels shown in Fig. 122 was devised and installed. It consisted simply of two 500 ohm relays representing the vertical and rotary relays. Their co-operation connects negative battery through 60 ohms resistance to the release trunk, which releases the switches as usual.

34. Trunk Repeaters

After a time the automatic telephone had demonstrated its ability to handle commercial exchange work in small and medium sized exchanges. But cities have a faculty of growing, and the telephone system must keep pace with the needs, which have had a habit of growing faster than the population. It is an unfortunate fact that as a central office grows in size, the

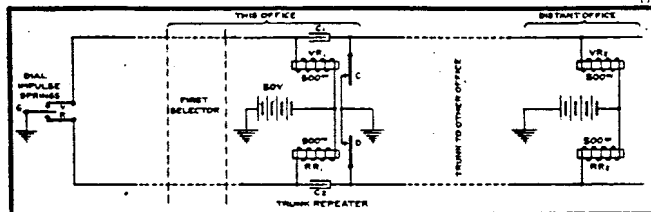


Fig. 123. Experimental Trunk Repeater, Which Did Not Work.

expense per year per telephone increases. The attempt to subdivide an exchange territory into districts, with a relatively small office in each, reduces the expense a little, but the annual cost still runs up in a marked degree.

The automatic system shows itself very flexible in being adapted to the conditions of multi-office exchanges. It permits the cost of service per line to be kept within bounds, and shows a decided economy in the subdivision of offices. The most notable example is the city of Los Angeles, Cal., in which there are one main office, manual, and seven sub-offices, all automatic, the latter serving between 15,000 and 20,000 out of the total of 35,000 subscribers. All the automatic offices are so linked by trunk lines that a subscriber can call to any of them with exactly the same ease and speed that he would reach another telephone in his own exchange.

As the lines became longer, it began to be noticed that the relays did not act as well as before. It was more difficult to adjust them so that they would respond accurately to the series of rapid impulses. This was caused by the electrostatic capacity of the lines. While pulling the first digit, the subscriber operated a first selector in his own office, the relays of which responded easily. But while completing his connection he was operating the relays of a connector in the distant office several miles away. The capacity, in that distance, has an appreciable effect on the behavior of the relays. It makes them sluggish, tending to hold up and not fall back promptly on each break of the dial.

The same problem had been met in telegraph work, and a satisfactory solution found in the repeater, which is now in daily use on hundreds of lines. So the engineers of the Automatic Electric Company set themselves to work to produce a repeater for trunk lines which should give relief.

It seems a simple thing to arrange a circuit like Fig. 123 to repeat the signals. The condensers, C_1 and C_2 , break the continuity of the line for battery current, while allowing talking current free path. All the vertical impulses made by the dial at the left operate the relay, VR_1 , which grounds the vertical line at the right of the condenser, thus passing the signals on to the vertical relay, VR_2 , in the selector at the distant office. The rotary impulses are similarly passed on.

It was in this form that the first trials were made. But it failed. The relays, VR_1 and RR_1 , acted sluggishly, or not at all. Examination into the cause revealed the following state

of affairs: When the impulse spring at the dial closes, it connects the left hand terminal of condenser C_1 practically "dead" to ground. When the vertical relay, VR_1 , pulls up as the result of the condition at the calling station it closes its contact, C , and connects the right hand terminal of the same condenser to ground. For an instant the condenser is thus short circuited, and hence is discharged. When the vertical impulse spring at the dial breaks, this short circuit is removed. Current will therefore continue to flow through VR_1 until the condenser is fully charged. This holds the relay up until the next impulse comes in, so that it "freezes," or sticks closed, or at least will not transmit signals clearly and reliably.

This difficulty was finally solved by reversing the vertical and rotary lines at the right of the condensers, C_1 and C_2 , as in Fig. 124. This was done about January, 1906, and the circuit was applied to the Los Angeles exchange with marked success. It will be observed that the vertical relay still repeats signals to the vertical line to the other office, but condenser C_1 is now connected to the rotary line to the right. It is no longer in a position to cause a continuation of current through VR_1 . When the subscriber releases, VR_1 and RR_1 pull up together, grounding both vertical and rotary lines at C and D , releasing the apparatus at the distant office. Contacts A and B close, feeding negative battery through the 60-ohm resistance to the release trunk, and thence to the apparatus in the home office, releasing it.

This type of repeater works perfectly for local battery systems, but for common battery there must be a modification. Fig. 125 shows the common battery trunk repeater as used at Portland, Ore., and also at Los Angeles, Cal., in the spring of 1906. The vertical relay, VR_1 , is in series with one winding of the differential relay, DR , and has a permanent connection to negative battery. The rotary relay, RR_1 , is connected in series with the other winding of the differential relay, from which the circuit goes through contact H of the talking relay, TR . Thus each side of the line to the calling subscriber has negative battery for selecting purposes. The talking relay, TR , is normally bridged across the trunk line, but is controlled by contact F of the differential relay. The vertical relay, through its contact C , passes the impulses on to the vertical line extending to the distant office. The differential relay follows all these impulses, disconnecting the talking relay from across the line. The impulse on the rotary line energizes the rotary relay, and, through its contact D , grounds the rotary trunk to the distant

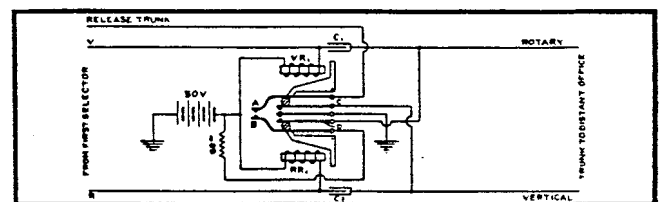


Fig. 124. Trunk Repeater as Installed at Los Angeles.

office. Again the differential relay pulls up, and disconnects the talking relay from the trunk.

When the called subscriber answers, the talking relay in the connector in the distant office pulls up, and switches the rotary trunk from negative to positive battery, i. e., ground. This causes current to flow over the rotary trunk to the trunk repeater, through contact F , talking relay, and back over the ver-

tical trunk. The talking relay is thus energized and pulling up accomplishes three results. At *K* it cuts ground off the contact of the vertical and rotary relays. At *L* it disconnects the contact *D* of the rotary relay from the rotary trunk. At *H* and *G* it switches the rotary line to the calling subscriber from negative battery to positive, thereby giving him battery supply for talking purposes. It will be observed that the vertical, rotary, differential, and talking relays have very much the same relations to each other and the lines as the relays of the same names in the common battery connector which was described in the preceding chapter.

When through talking, the called subscriber hangs up, releasing the talking relay. This changes the rotary line of the calling subscriber back to negative battery, so that when he hangs up and grounds both lines, the vertical, rotary, and differential relays will all pull up. Contacts *C* and *D* ground the trunk line, and thereby release the apparatus in the distant office. Contact *E* of the differential relay feeds negative battery through the 60-ohm resistance, and the *A-B* contact, to the release trunk, which releases the apparatus in this office.

The calling subscriber can release even if the called subscriber has not hung up. In this case the talking relay is still energized. If now both lines from the left be grounded the rotary relay and the bottom winding of the differential relay will be short-circuited. This allows only the vertical and differential relays to pull up, the latter disconnecting the talking relays at *F*. The talking relay falling back gives negative battery to the rotary line (at *H*), making the rotary relay also pull up. This closes the contact *A B*, and since *E* is already closed, negative battery is fed over the release trunk to release the apparatus in

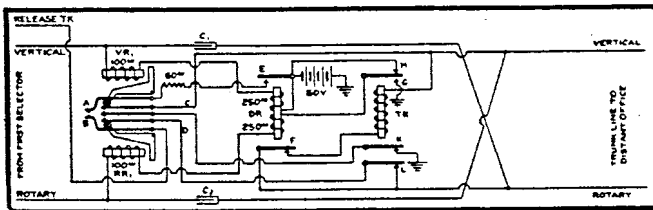


Fig. 125. Common Battery Trunk Repeater.

this office. At the same time contacts *C* and *D* release the distant office.

A very interesting combination of selector and trunk repeater was put in at Columbus, Ohio, in the spring of 1907. Its circuit is given in Fig. 126. Since it was designed for a local battery system, the vertical and rotary relays are permanently connected to negative battery and the lines as shown. Two condensers, C_1 and C_2 , separate the lines to allow the separation of battery feed. The wires to the vertical and rotary wipers are transposed to avoid the trouble described above. Contact *C* of the vertical relay normally operates the vertical magnet, *VM*, but after the selector action is over, it is made to ground the vertical trunk like a repeater. Contact *D* of the rotary relay also does double duty, handling the private magnet, *PM*, and also the rotary trunk line. Detailed description of its action does not seem necessary, as each action has been thoroughly explained before.

One very important use of the trunk repeater is in the "sub-office" plan of exchange division. In this plan a group of subscribers who would ordinarily be served by lines direct to the main office have their line-switches and connectors moved out to a point in their neighborhood. From this sub-office only as many trunks are carried to the main office as are necessary for the traffic. It has been found to give better satisfaction to cut in a trunk repeater at the sub-office in each trunk going to the main office. Such a trunk repeater, adapted to common battery, is shown in Fig. 127. It will be remembered that in the common battery line-switch, its release magnet is connected from negative battery to the release trunk when a subscriber

has tripped in. Hence contact *E* of the differential relay needs only to ground the release trunk to cause the restoration of the line-switch. An off normal relay, *ONR*, is added, which connects the talking relay across the trunk when the line-switch trips in, the current being fed through the release magnet of the line-switch. Owing to its high resistance, 5,500 ohms, it will not affect the release magnet.

By the introduction of the repeater the sharpness and relia-

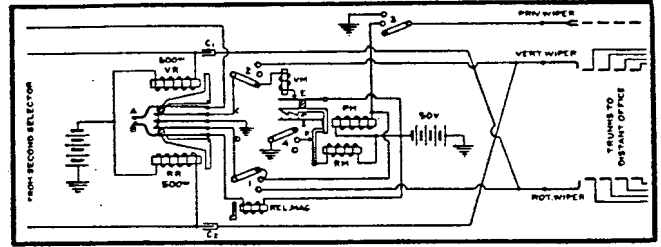


Fig. 126. Circuit of Third Selector and Trunk Repeater Combined.

bility of the signals was made all that could be desired. But an added point in favor of the repeater was brought out in connection with the common battery system. Without it, the calling subscriber had to draw his talking current from the connector in the distant office. This gave him relatively weak transmission. With the repeater, he draws current from battery in his own office, as the called subscriber does from his own office, and voice transmission is made very much more satisfactory.

35. The Lorimer System

Probably no other part of telephone history contains a parallel to the development of the Lorimer system, arising as it does from the skill of the three brothers, who worked courageously and consistently for ten years before producing a working system.

George W. Lorimer was born April 15, 1874, at St. George, Ontario, Canada. His brother, James Hoyt Lorimer, was born in 1876, while the youngest brother, Egbert S. Lorimer, was born in 1880. Their father was owner of a sash and blind factory, also making a clothes wringer, the patent on which he owned. George, even when very young, showed a mechanical tendency, being interested in the steam engine and water wheel which ran the factory. At the age of 12 he made a working steam engine. Both George and Hoyt received a good common school education, also a high school course at Scotland, Ontario. Hoyt was started into the study of law, while George, in the spring of 1888, left school and took the examination for teacher's certificate. Failing in but one subject, bookkeeping, his father insisted that he learn it perfectly, and he was sent to the Brantford Commercial College, from

which he graduated in 1889. He at once secured a position with a firm in Bay City, Mich. In the spring of 1891 his father died and, acceding to his mother's desire to have him nearer home, George left the Bay City firm. Not liking bookkeeping he started to learn telegraphy in a railroad office in the fall of 1891, in his home town, St. George. While learning to be an operator he studied "Freight and Tickets" in addition, so that from the spring to fall of 1892 he was employed as relieving agent.

During this time Hoyt had been pursuing law after a fashion, but he was much more interested in electricity than in dry books and nice points in equity. Finally, because he persisted so much in making electrical experiments in the law office, his employer told him that he was not cut out for the study of Blackstone.

There was in the city of Brantford a music teacher named Romaine Callender. He was an ingenious man, and of an enthusiastic temperament. He had located in Brantford years ago. In connection with his musical work he had invented an organ player, the patent on which he sold for \$200. His

attention was directed toward the telephone as a field for his activities, and he began the invention of an automatic switch-board.

As soon as Hoyt Lorimer was told of the futility of the study of law he went at once to Mr. Callender and offered his services in the experimental shop. To his delight he was accepted, and set to work in the shop on Dufferin avenue, making parts of the apparatus. Hoyt soon became infatuated with this work, and induced his brother George to leave his railroad work and enter Mr. Callender's employ. The latter was glad to get the additional assistance of one who had the practical experience of a telegraph operator.

36. Callender's First System

The general features of the system on which Mr. Callender was at this time working are shown by Fig. 128. It would be useless to go into the details, as they are complicated and for the most part uninteresting. At the middle of the top of the figure are the subscribers' lines, which are of the single wire ground return type. All these lines pass through the general circuit breaker, to the banks of switches or circuit selectors. Each line is also connected through the "isolator" at the left to a single switch, called the "numerical receiver No. 1." The substation, Fig. 129, was equipped with a battery, *BA*, and an impulse transmitting cylinder, *T*. Each of the bars, *a*, was connected through the brush, *y*, to battery. The switch lever, *Sw*, was connected to line 1, leading to the office. By mere inspection of Fig. 129 it will be seen that if the switch lever, *Sw*, be placed on any of its contacts, from 0 to 9, and the crank *H* be turned one revolution, there will be a certain number of impulses sent over the line to "Central."

By placing the switch at *O* and sending thus one preliminary impulse, the isolator (Fig. 128) severs all lines except the one calling. A series of impulses now sent from the substation will actuate the numerical receiver No. 1, rotating it by a magnet and ratchet to the desired point. From here on Mr. Callender's scheme is vague and unsatisfactory. He intended to have all numbers from 1 to 9 called by means of

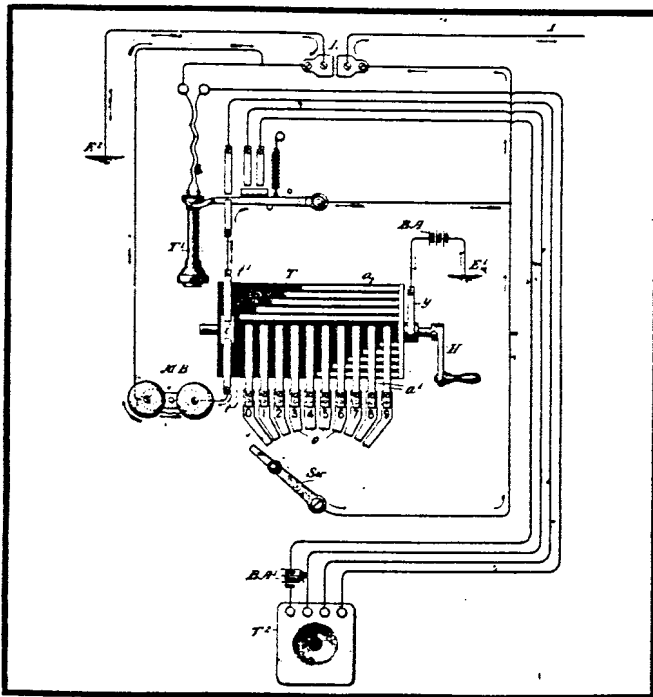


Fig. 129—The Substation of the Callender System.

numerical receiver No. 1 only, yet to have this same switch pick out any one of the second series (numerical receiver No. 2) or third series (numerical receiver No. 3) to get numbers as high as 999. As shown in the figure, this is impossible. With-

out rehearsing the details of the apparatus, the following summary will show the main points:

1. Ground return subscribers' lines.
2. Local battery for selecting.
3. Free use of relays and magnets.
4. Only one subscriber could use the apparatus at a time,

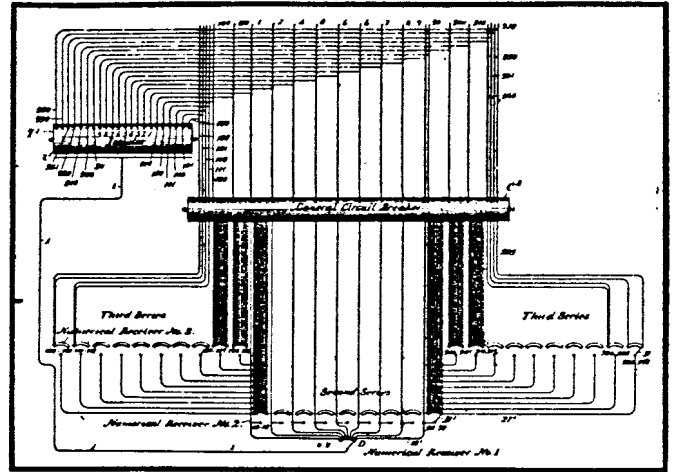


Fig. 128—General Features of the First Callender System.

since all calls from the entire exchange had to use numerical receiver No. 1. All others would have to wait until he got through talking.

5. The release was to be automatic at the end of a fixed time, determined by a clock, and not under the control of the subscriber. However, he could release before, if he got through.

6. The ringing was to be done automatically.

7. Complication was added to complication to secure simple results. He seems to have had the idea of doing everything by time-limit, even where not needed.

8. The talking circuit had to pass through one relay.

9. He had the idea of primary and secondary switches, but the idea was not worked out into a consistent system.

During the spring of 1893 Mr. Callender devised a new form of time limit, employing a vibrating mechanism which was intended to act as a circuit changer when it came to rest. It was of doubtful utility.

37. Callender's Second System

He also devised another system (in the spring of 1893) in which for the first time was embodied the percentage idea, that is, the idea of providing only enough apparatus to perform the switching at the busy hour, and placing it at the disposal of any subscriber in the system. He also proposed to use metal balls to complete the actual connection, the selectors merely carrying and directing the balls along the desired channels or runways. After performing this act, the selector was to revert to the use of any other subscriber. The main features were as follows:

1. Two-wire system—no earth return.
2. Local battery selecting.
3. The percentage idea.
4. Circuit selectors not to make the connections, but to swing around and deliver metal balls to runways, the balls rolling along to a pocket where they dropped onto plates and connected the lines.
5. Constantly rotating percentage circuit selector, to be seized by any one of the subscribers and made to give a circuit selector into the control of the subscriber.
6. Circuit selectors to revert to common use after discharging the balls.
7. Primary and secondary circuit selectors. The former were to pass balls to any one of the latter, and the latter to pick out the proper runway and deliver the balls to it.

8. Limited size, due to the form of connecting board. This was similar in plan to the telegraph switchboard used at way stations, except that the balls made the connection between the intersecting conductors instead of pins.

The World's Columbian Exposition was set to occur at Chicago during the summer of 1893, and the men who were backing Mr. Callender desired to have a working exhibit there.

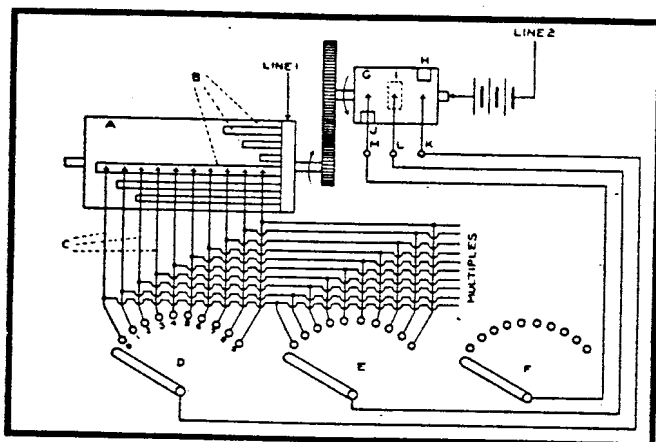


Fig. 130—Callender's Signal Transmitter.

This he promised to do, intending to use the above system. But the machine was an utter failure, and was abandoned before completion.

The money for the experiments had been furnished by two of his friends, Dr. E. Hart and Mr. Gould. During the summer of 1893 their money began to be scarce, so all of the men were laid off except Hoyt Lorimer. George was to be re-employed as soon as conditions became better.

Finding that the ball idea did not work out for connections, a new circuit selector was devised to make the contact directly. A magnet on a revolving shaft was made to lift any one of a series of contacts and make it touch an interconnecting ring. After this, the revolving magnet could go on for other calls. A new signal transmitter was also produced, which is of interest in relation to the later work of the Lorimers. The object was to get up a device which would automatically send in the required number of impulses for each digit in the call number, after being set by the user. Its principles are shown in Fig. 130. *A* is a drum on whose surface are metal bars, *B*, of varying length. *C* are brushes resting on the cylinder, each brush being connected to one contact of the switch *D*. The contacts of the other switches, *E* and *F*, are multiplied to those of *D*, point for point, as indicated. *G* is another insulating cylinder geared to *A* by a 3 to 1 gearing, *G* moving the more slowly. The contact segments *H*, *I*, and *J*, are connected through battery to line No. 2. The brushes *K*, *L*, and *M*, are wired separately to the switch arms *D*, *E* and *F*, respectively.

The subscriber sets each of the switches *D*, *E* and *F*, to the proper digit values of the number he desires. He then pulls a chain or lever which winds up a spring. When released this spring, regulated by a governor, drives the cylinders *A* and *G*, around in the direction arrowed. During the first revolution of *A* the brush *K* is in contact with *H*, so that the number of impulses sent will depend on the position of *D*. During the second revolution of *A*, cylinder *G* will have turned so that segment *I* touches brush *L* and the impulses sent in will be fixed by the position of *E*. In the same way the last series of impulses is fixed by *F*.

After being laid off by Mr. Callender, George Lorimer was for a time at his home at St. George, but Jan. 1, 1894, he started in electrical business for himself in Brantford, putting

in intercommunicating telephone systems, electric bells and annunciators, and also selling supplies. At this time he invented an automatic switch return for the intercommunicating system.

Callender's Move to New York.—Since the funds of the Brantford men had run low, Mr. Callender cast about for an additional source for means to carry on the work. Mr. J. Hood Wright, of New York, offered to advance money for the purpose on condition that he move his operations to New York. To this Mr. Callender agreed, and in the spring of 1894 he made the change, taking Hoyt Lorimer with him. After arriving in New York he wrote for George Lorimer to come also. This he did, arriving in the city a few weeks later.

Mr. Callender selected and rented fine rooms on the tenth floor of the Decker Building. Here a comfortable office and private laboratory were fitted up for him. A general workshop was arranged for the Lorimer brothers. Here for a year or more the development was continued. At first they tried to construct a system based on the old plans in Brantford. But new difficulties were encountered, which led to the construction of a still different plan.

38. Strowger and Callender Compared

It will be highly instructive at this place to get the viewpoint of Mr. Callender in his endeavors, and compare it with the line of attack followed by the developers of the Strowger system, whose history has been treated previously. It will be remembered that Almon B. Strowger started with the simple conception of a cylindrical switch with ten rows of inside contacts, each row having a hundred contacts; an axial shaft carrying a spring or wiper and adapted to be raised to any row and rotated to any point in that row, the latter motion being made in two ways, first in jumps of ten notches each for the tens digit, followed by individual steps for the units.

Since that day other switching devices have been tried, only to return to the cylindrical bank and the axially mounted wiper. The bank has shrunk from 1,000 circuits to 100, and occupies only a portion of a cylinder. Except in the case of the connector, the vertical motion has been made to select groups, the rotary being devoted to seeking a non-busy trunk.

In his second New York system Mr. Callender made the real start which, later, under the remarkable work of other hands, developed into the Lorimer system, though the latter is very little like the former. To show the germ principle of Callender's system, Fig. 131 has been prepared. Suppose that we have a number of concentric metallic conducting rings, 1, 2, 3, etc., as many as are necessary to serve the traffic of the

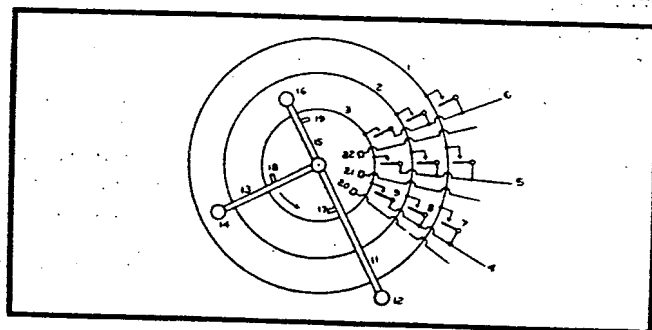


Fig. 131—Scheme of Callender's Selector-Connector.

exchange. 4, 5, 6, etc., are three of the 100 subscribers lines which enter the system. The single line and ring must be understood to represent as many separate conductors as are included in one circuit. If, now, by some means we can con-

nect two of these subscribers' lines to any one of the rings, those two will be able to talk to each other. Further, it is necessary to provide only enough rings to serve the largest number of connections which may be needed at any one time. From the records of those days it was taken to be ten per cent of the lines, which would give ten rings for a 100-line exchange. This is known as the percentage idea, and is now known to be the only correct basis for arranging exchange apparatus. It is in sharp contrast to the early Strowger idea, which for many years followed the starting point of individual switching mechanism.

39. Callender's New York System

The means by which Mr. Callender proposed to connect the lines to the rings is briefly given in the following description: In Fig. 131, 7 is an iron armature which normally lies down clear of the ring 1, but when raised will connect line 4 to ring 1 and stay there until pushed down again. Eight is a similar device for connecting line 4 to ring 2, while 9 is for ring 3. In a similar way each of the hundred lines is equipped with iron armatures for connecting any of them to any of the rings.

Carried by a central shaft, 10, which is maintained in constant rotation by a motor, is an arm, 11, carrying on its end an electromagnet, 12. During its revolution magnet 12 passes over all the iron armatures which may connect with ring 1. Mounted on another arm, 13, is a magnet, 14, which governs all the armatures connecting to ring 2, while arm 15 carries magnet 16, which presides over ring 3. Each conducting ring, its revolving magnet, and accessory apparatus is termed a "division." The sub-station apparatus was the same as described in the last chapter.

The plan was to have the sub-station (No. 4, for instance) send in a preliminary impulse which should render its contact plate (20) electrically alive. As the shaft is constantly revolving, the wipers, 17, 18, 19, etc., of the various arms, will pass over all the contact plates in succession. After a subscriber, by the preliminary impulse, had rendered his plate (20) alive, the first brush (17) thereafter to touch it would momentarily energize its magnet (12) causing the iron armature (7) corresponding to both line and ring to be pulled up, thus connecting the two. A series of impulses are now sent in by the signal transmitter at the sub-station, which has indirectly the effect of energizing the magnet (12) of the same division just as it passes the called line, pulling up its armature into contact with the same ring (1), thereby establishing electrical connection between the two subscribers. A single release relay was to be left connected to the circuit, which on an impulse from the calling subscriber energized a release magnet mounted on the revolving arm of the division used, which during one revolution moved a lever down so as to press down all armatures in that particular circle. The working out of the above ideas called for considerably ingenuity.

Each subscriber's line was equipped with an individual switch, which was progressively rotary, with six positions. After each use it was returned to normal by being rotated ahead to the end of 180 degrees, which constituted its cycle. The preliminary impulse, which was, like all the selecting impulses, furnished by local battery at the sub-station, stepped the individual switch off normal, which brought into play a circuit which energized the seizing magnet of the first division to pass that line. This in turn moved the individual switch

another step so that the impulses from the sub-station would reach the "numerical receiver," or "signal register," which consisted of a wiper arm swinging over a bank of contacts. This was used to indicate the number of the called line. It was not a part of the talking circuit, but was used merely to cause the same division to pick up or seize the correct line.

For each "division" there were two signal registers (a units and a tens receiver). Their arrangement is shown by

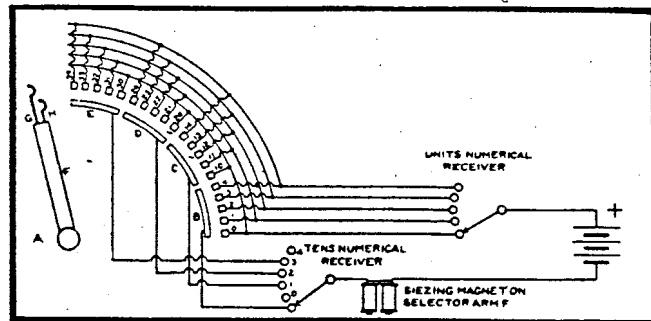


Fig. 132—Callender's Numerализing Scheme.

Fig. 132. Let *A* represent that part of the selector-connector which has to do with "numerализing," that is seizing the called line. Let the series of contact plates 0 to 4, 10 to 14, 20 to 24, etc., be the individual contacts, one per line. The contacts 0 to 4 are supposed to represent the full ten from 0 to 9, also 10 to 14 may be taken for 10 to 19, so that there will be a full hundred lines around the circle. These individual contacts are multiplied to the bank of the units numerical receiver, so that like units digits are wired to the same plate. Hence, 2, 12, 22, etc., are wired to point 2 of the units receiver bank.

B is a segment of a feed ring lying opposite the ten contacts 0 to 9, *C* is a segment opposite the contacts 10 to 19, etc. Each segment is wired to a bank contact of the tens numerical receiver, *B* going to the normal contact, *C* to the 1 point, *D* to the 2 point, etc.

The constantly revolving arm, *F*, of the selector-connector carries a pair of bridging brushes, *G H*. *G* wipes over the units contacts, and *H* over the tens segments, *B, C, D*, etc. In circuit with the two receivers are battery and the seizing magnet. The latter is mounted on the rotating arm, and is the one which lifts the armatures of the line into contact with the connecting ring of its division. As long as both numerical receivers are at normal the circuit is broken and the arm and magnet rotate with no effect. Suppose the subscriber who gets the use of this division calls subscriber No. 2. He will accordingly send in three impulses, which by a circuit not shown steps the units numerical receiver around three notches to the point marked "2." This makes all the No. 2 contacts (2, 12, 22, 32, etc.) "alive" with positive battery, but only segment *B* is connected to the seizing magnet. Hence when the brushes *G* and *H* wipe past the contact 2, the magnet will be momentarily energized, thereby lifting the armature of line No. 2 into contact with the ring of that division.

If a call is made for a number higher than 9, two series of impulses are sent in from the signal transmitter at the sub-station. The units impulses come first, followed after a brief interval by the tens. As these two series come over the same wires, but must be made to affect different receivers, some means must be used to switch the second series to the tens receiver. Here Callender attempted to use a vibrating reed, calling it a "numerical separator." The end of the reed wiped past a fixed contact. As long as the units impulses were coming in the reed kept vibrating, not making contact long enough to have effect. In the interval between the units and the tens impulses the reed came to rest, and closed contact long enough to operate a circuit which switched the line to the tens numerical receiver.

Accordingly, if a call were made for No. 32, the units receiver was first stepped around to point 2, then the tens receiver was set to point 3. This secured the picking up of line 32.

Each division included the following apparatus: three connecting rings and three magnets on the selector-connector, two numerical receivers (units and tens), a percentage controlling switch, a signaling track and ball, and a release relay. The percentage controlling switch had many of the functions

of a side-switch, shifting circuits at various points during the progress of making a call. The signaling track consisted of two conducting rails on which rolled a copper ball. The track was divided into fifteen sections. The ball was released after the number of the called line had been recorded on the numerical receivers. The ball was used to prevent a line from being called by two people at once, and to store up the second call. It also closed the numeralizing circuit described above, rang both bells, gave the busy signal if the called line were busy, and helped in the release.

When it came to actual trial the vibrating "numerical separator" failed to give satisfaction. Its place was taken by a weighted lever mounted on the arm of the units numerical receiver. While making the progressive motion forward the circuit was held closed onto the units receiver motor magnet by inertia. But when the arm stopped, the weight fell forward switching the line to the tens receiver.

Events at New York.—The work which was being done in the Decker building in New York attracted some attention, and the apparatus was viewed by numerous people who might be interested financially. On Jan. 12, 1895, the *Electrical World* published an account of the system, giving views of the apparatus and a popular description of its operation. Though it came nearer working than the machines made at Brantford (which were a total failure), the New York apparatus could not be termed a success. On one occasion it worked for about a dozen calls with success, and without the usual coaxing of the switches. This was considered phenomenal.

In the summer of 1895, Egbert Lorimer, the youngest of the brothers, who was still in Brantford, Ontario, was taken with typhoid fever. Since the death of the father, George was the natural head of the house and at once went home to take care of his brother. Soon the mother also came down with the dread disease. Faithfully he took care of both of them through that illness in which nursing is such an important factor, and finally had the pleasure of seeing them on the road to health. But early in September he received word that Hoyt, who was in New York, was sick with typhoid fever. So George hurried to New York to look after him. He was sent to the hospital, where for two long months he battled against death.

During the month of September Mr. Callender went to Europe. He had been contemplating the trip for some time. The salaries of the Lorimer brothers were small and little or no money was left them for expenses during Mr. Callender's absence. With the conditions of living as they are in New York, it is no wonder that before Mr. Callender's return they got into straightened circumstances.

Early in November Hoyt had recovered sufficiently to be discharged from the hospital. During his sickness the doctors had used the ice-pack treatment, then much in vogue. Neither boy had an overcoat, which Hoyt in his weakened state sorely needed. One day George saw an advertisement of a place away down town where an overcoat could be bought for \$5.70. Counting up their store of money they found just \$5.70 on hand. No money for car fare! So both boys walked a good number of miles to get the overcoat to protect the weaker from the chill November wind.

About the middle of November Mr. Callender returned from Europe, and as soon as money could be had Hoyt was sent home to Brantford to recuperate.

40. The Return to Brantford

During the past year considerable feeling of dissatisfaction had arisen on the part of the Brantford investors, whose money was still tied up in the invention. They wished him to come back to Brantford, form a stock company, and carry on his future operations there. This Mr. Callender did not wish to do, and sent George Lorimer, in the late fall of 1895, to treat with the Brantford men for different terms. But they

were firm, demanding the return to Canada. So Mr. Lorimer returned to New York at once. About the middle of January, 1896, Mr. Callender returned to Brantford. George Lorimer was left in New York to clear up the rooms, sell what junk he could, ship the usable part of the goods, and come to Brantford later.

Shortly after this the Callender Telephone Exchange Company, was formed, according to the agreement. Mr. Callender was retained as consulting engineer, with George and Hoyt Lorimer as engineers. Mr. Callender spent much of his time developing a new scheme of his for rapid telephony, employing Egbert Lorimer to make some of the apparatus. The other two brothers continued working on the automatic system under Mr. Callender's directions, though there was a growing estrangement between the latter and the company. On one occasion there was a small difference of opinion between him and George over the safety of a grinding machine in the factory, after which he was not often seen there. About July or August, 1896, Mr. Callender severed his relations with the company. He was then engaged in working up a company to take hold of his rapid telegraph scheme. He soon went to England, where he organized the Callender Rapid Telephone Company.

After Mr. Callender left, Mr. Neill and others had conversations with the Lorimer brothers regarding the future work. The latter, while constructing the apparatus under orders, had been doing considerable thinking for themselves. They had seen the failure of the work, and thought they knew how to overcome it. After hearing their ideas explained, the company told the boys to go ahead and spend the money necessary to work out their ideas, as they believed them to be all right.

Some time this year (1896) a franchise was secured for an automatic telephone exchange at Troy, Ohio, and the construction of the switchboard was begun at Brantford. In October Hoyt was sent to Troy to superintend the building of the wire plant, in which he took great pride, making it a good, neat job. On account of Hoyt's poor health, George took most of the indoor machine work and the heavier tasks, to allow his brother the benefits of outdoor exercise as much as possible.

The new system which was to be installed at Troy was a direct successor to the second New York board described in the previous chapter. But in place of the bulky and cumbersome selector-connector, a number of discs were used. These discs were of rubber, and were mounted vertically in pairs on a horizontal shaft. One of each pair contained contacts for all the lines in the exchange and was stationary. The lines were multiplied to all the stationary discs. The other disc of each pair was mounted to revolve on the shaft and carried the connecting brushes. Its connection to the shaft was frictional, and could be stopped by a magnetically released bolt, shooting into a series of teeth on its rim. Each line had an individual switch of different pattern from the New York style, but which changed the circuits from time to time in much the same way.

While the apparatus was nearing completion, George Lorimer noticed some inherent defects and the brothers had considerable correspondence over it. The system was completed, set up and tested out at Brantford in December, 1896, and January, 1897, and in February was shipped to Troy, Ohio. George came also at the same time to erect it in place. Now it is one thing to set up apparatus in a shop and make it work, but to secure satisfactory results in commercial use with the public to do the manipulating is a very different matter. Since it had developed weakness even in the factory, the system could not be expected to do better in practical use. And it was even so, for there were plenty of difficulties to test the ability of the young inventors. For one thing,

the numerical separators did not act very well. To get around this, George tried various things, among which was a rubber tube containing mercury. A circular row of contacts was arranged just below the surface, so that if the tube were tipped a little, one or more of the contacts would be out of the mercury and the circuit broken. When the tube came to rest the circuit would close and perform the switching. But this did not solve the problem. The individual switches were also trouble breeders, and the disc circuit selectors were not far behind. At times the brushes of nearly all the selectors would get in line with each other. On the next call coming in, all these selectors would stop on the same line, thus tying up the system until that subscriber got through. It soon became rare for a call to go through the exchange without trouble, and the system was finally abandoned late in 1897.

41. Beginnings of the Lorimer System

Shortly after arriving in Troy, George Lorimer consulted with his brother Hoyt as to means for overcoming the weaknesses of the system, and in March, 1897, partly devised the mechanism for doing it. They made sketches and talked it over with Mr. N. D. Neill, who was general manager of the company and their close friend. He was a practical man, keenly alive to the commercial needs and the difficulties which had been encountered. Seeing that the germ idea was good, he raised more money for development and told the boys to go ahead. In May they began work on an apparatus to try out certain principles involved which would demonstrate the correctness or fallacy of their ideas. The boys were boarding in Troy, where they were installing the exchange, but for better facilities a location in Piqua, Ohio, a few miles north, was chosen in which to do the experimenting. They went back and forth as occasion demanded. The apparatus was completed in the last part of August, 1897. It was very crude, not a complete exchange, but did the work.

Departure from Old System.—Since the Lorimer brothers had been working with the Troy, Ohio, exchange they had been impressed with the futility of trying to make an automatic switching system on the plan there used. The troubles encountered, with the proposed remedies, are as follows:

1. The individual switches gave endless trouble. Hence, have none of them. Let their circuit shifting duties be performed by apparatus which is a part of a division.
2. The circuit selectors got in line with each other so that several might be seized by one line, thus reducing the chance for other people to talk, or, in certain cases, tying up the whole plant. It was now proposed to have the circuit selectors normally at rest. The remedy also involved a constantly rotating device, called a division starter, whose duty should be to detect a calling line, and start out one circuit selector (part of a division) to find it.
3. The numerical separator could not be made to give satisfaction. Hence, do away with it. Let the impulses come in over one wire and ground, while the other wire

and ground form a circuit for controlling the action of the signal transmitter (at the substation). By this means the second or third set of impulses may be held up positively till ready for them.

4. The fact that each circuit selector had to contain around its edge terminals for all the lines in the exchange limited the size of the system. The Lorimer brothers proposed to have the switchboard built in sections of 100 lines each, so arranged that calls would be trunked from one to the other. Further, it was their object to make the section the unit, adding sections as the exchange grew.

Fig. 133 shows as nearly as possible the scheme worked out to do away with individual switches. It is the apparatus which was set up in the spring and summer of 1897 to demonstrate to Mr. Neill, the manager, that their ideas were feasible. The sub-station is an adaptation of that used at Troy, with the addition of a trip magnet, *T M*, to control the movement of the impulse brush, 32.

The preliminary impulse receiver consisted of a stationary commutator, 4, having as many segments as there were lines in the exchange. Line No. 1 of each subscriber's line was to be wired to its own segment. The stop

relay, *S R*, was wired between positive battery and a constantly rotating brush, 2. The stop relay, *S R*, by means of its contact, 1, could energize its own stop magnet, *S M*, and the division starter relay. The former operated a clutch and bolt, by means of which it could disconnect the brush, 2, from the power shaft and stop it on any desired segment. The division starter relay energized the operating magnet of another apparatus called the "division starter." This consisted of a cylindrical arrangement of contacts, with a set of wipers on a shaft rotated inside. The operating magnet, *O M*, stepped the wipers forward.

The rotary switch was a similar cylinder of contacts, but the brushes or wipers were adapted to be moved by a power driven shaft, which a clutch magnet, *C M*, could connect or disconnect.

The primary connector was similar to the rotary switch, except that very special means were taken to insure quick and accurate stopping of the wipers. The bolt, 27, was held normally in a notch of a wheel, 26, by spring pressure. The clutch magnet, *C M*, could pull the bolt, 27, out and thus allow the wipers, 22, 23, etc., to begin to rotate. A dog, 28, then snapped to catch and hold the bolt out till released by the bolt release magnet, *B R M*. To the bank contacts, 24, 25, etc., were wired the subscribers' lines.

The action was as follows: To send in a call a lever or chain at the sub-station was pulled down. This wound up a clock spring, and also moved brush, 32, onto the first pin, 31, of its bank. This grounded Line 1. At central brush 2 is continually revolving and in course of a fraction of a second strikes segment 3, to which Line 1 is connected. At once the stop relay, *S R*, is energized, which energizes the stop magnet, *S M*, and the division starter relay. The former stops the brush, 2, on segment 3, the latter starts the brushes of the division starter. As the two bridged wipers, 6 and 7, of the division starter move over the contacts, 8 and 9, they close a circuit as follows: from positive battery through *C M*, to negative battery, which is grounded. This pulls out the bolt, 27, of the primary connector, locked by dog 28 and immediately the wipers 22 and 23 start to find the calling line.

The bolt has closed a contact, 29, from negative battery which sends current through contact 17, brushes 11 and 10, and contact 16 or the rotary switch (normal position) to stop relay, *S R*, thereby locking the brush, 2, in its position. Bank contact 25 of the primary connector is the one connected to Line 1, and is the one which will determine the identity of the calling line. It will be noticed that normally this point is open. But since a call has been initiated, point 25 and Line 1 have been "dead" grounded by the contact 29 through the brush 2. Thus wiper 23 is hunting a "dead" ground, where it will stop.

Following the wire attached to wiper 23, we find that it runs to contact 20 of the rotary switch, through bridged brushes 14 and 15 (normal position) to contact 21, from where it goes through *C M*, and *B R M* in parallel to positive battery. Hence, when wiper 23 strikes the ground on 25, both magnets will be energized. The bolt release magnet, *B R M*, lets the bolt 27 shoot into a notch, stopping the wipers, 22, 23, etc., on the calling line. Contact 29 is opened so that the brush, 2, of the preliminary impulse receiver can start again on its rounds.

The same current that energized the bolt releases magnet also pulled up the clutch magnet, *C M*, which started the rotary switch wipers on to their next stop. While the bridged brushes 12 and 13 wipe over contacts 24, Line 2, through the trip magnet, *T M*, to ground. This releases the clockwork so that the brush 32 is made to travel forward, sending in a series of impulses over Line 1.

As the apparatus was not designed to make complete

talking connections, no further work on it was done, except to make drawings of the apparatus and circuits, which were completed in August, 1897. On testing this rudely constructed apparatus the results were so satisfactory that plans were at once laid for building a larger model to handle complete connections. The shop was moved to

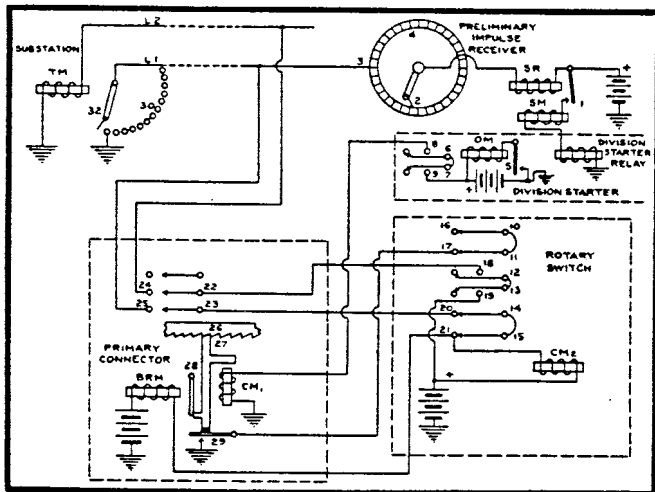


Fig. 133. Lorimer's First Plan for Doing Away with Individual Switches.

the Orr Building, on the corner of Wayne and Sycamore Streets (Piqua, Ohio) where a working model was completed. Its preliminary impulse receiver had four segments, but only three lines were connected.

Interwoven with the endeavors of life we may find many a romance, hidden from general view. The world sees only the struggling inventor, gradually perfecting his machine. But the inventor is a man. To him, his invention is often more than a machine. Its success may bring with it the realization of other dreams, perhaps the establishment of a home. It is significant that on the 26th of October, 1897, George W. Lorimer was married.

This exchange for four lines, three of which were connected, had the following parts, which it may be well to remember: Sub-station set, preliminary impulse receiver, division starter, rotary switch, and primary connector, all of which were part of the first outfit, made for demonstration only. In addition to the above there were the following: secondary connector, totalizer, a hundred's register, a ten's register, a unit's register, an interconnector, a signaling relay, a busy call relay, a release relay and a secondary connector controller.

The interconnector is worthy of special note, for it corresponds to a selector in its functions. After the hundreds register, by a series of impulses from the sub-station, has been stepped around to the position corresponding to the desired hundred, the wipers of the interconnector commence rotating and stop automatically when they have reached a non-busy trunk. This is a very fundamental action, for without it a large exchange could not be operated.

On the successful test of this first exchange, considerable machinery was bought and work commenced on a larger exchange to accommodate twelve lines. Two divisions were completed and tested out March, 1898. It worked perfectly, and for a long time was kept in use from one part of the factory to another. As no patent had been applied for, the place was carefully guarded and no public demonstration given, though interested people were shown its operation. At once they started to make eight other divisions, which were completed in the fall of 1898 or spring of 1899.

42. Remodeling the system

—In the spring of 1899 the Lorimer Brothers wished to put the system on the market. It was working finely, and they claimed with good reason that they had fulfilled their part of the contract in producing a working automatic exchange. But with his usual foresight, Mr. N. D. Neill viewed the apparatus as too cumbersome to be readily shipped. Accordingly he opposed placing it on the market at once, and urged the boys to begin reducing its size and designing it with a view to commercial conditions. At first both boys resisted the idea. Soon, however, Hoyt Lorimer saw the wisdom of Mr. Neill's suggestions and joined in urging his brother George to begin on a new system.

The principal objection was to the connectors (primary connector and secondary connector, identical in build) which were about sixteen inches high and the same in diameter, made of plaster of Paris, with all the division wipers and clutches inside, where repairs were difficult. The plaster bank was difficult to make and handle, several of them being broken in process of assembly.

Fig. 134 shows one view of the old system, at the ex-

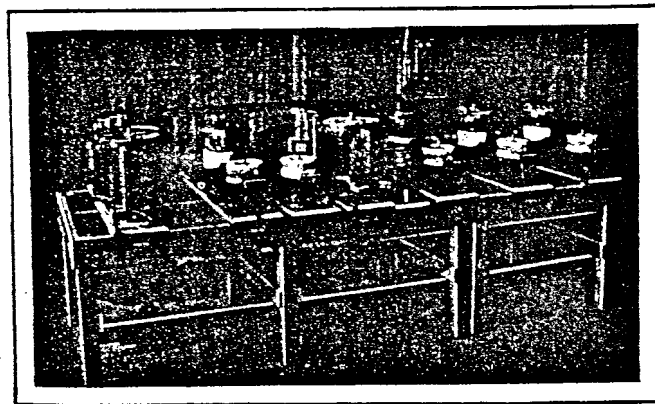


Fig. 134. Front View of Old Lorimer Automatic Exchange.

tre left of which may be seen the secondary connector. The right half of the bank has been removed, exposing the ten horizontal discs, each mounted on the vertical shaft and carrying a set of brushes. At the center of the picture is the primary connector, exactly the same in appearance and construction. The completely circular bank of the primary connector contains ten rows of contacts, with 100 sets of contacts in each row. Each set of contacts represents one subscriber's line and all corresponding sets in all the rows are tied together. Each of the ten discs belongs to a division and has the duty of picking up the calling line.

The location of the various parts of this exchange are given by the key in Fig. 135. A view of the opposite side of the exchange is given in Fig. 136, in which the totalizer is nearest the observer. Toward the left may be seen the preliminary impulse receiver, very similar in form to the totalizer. The exact circuits and construction of this exchange will not here be described in detail, but only enough of the functions and relations of parts given to make clearer the action of the latest development of the Lorimer system.

1. There is no individual apparatus; all is on the percentage basis. Each line is represented by ten sets of contacts of the primary connector and also on the secondary connector, and one contact on the commutator of the preliminary impulse receiver and also the totalizer.

2. The brushes of the preliminary impulse receiver are the only continuously rotating parts.

3. A division of apparatus (corresponding to a cord cir-

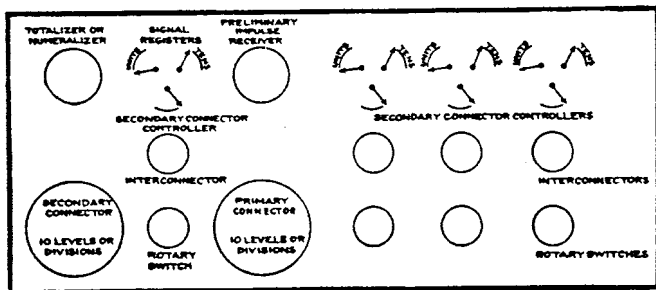


Fig. 135. Location of Parts Shown in Fig. 134.

cuit) comprises one of the ten brush carrying discs in the primary connector, a rotary switch, an interconnector (with the hundreds signal register on it), the units and tens signal registers, and a secondary connector controller.

4. On receiving a call, the preliminary impulse receiver stops its brush on the calling line, the division starter starts a division of the primary connector (the brush carrying disc) to hunt the calling line. When the line is found, the preliminary impulse receiver goes on revolving.

5. The rotary switch shifts the connections of the division at various steps in the call and controls the signal transmitter at the sub-station.

6. The hundreds register on the interconnector now receives the series of impulses selecting the group. The interconnector then automatically selects a non-busy trunk to that group. Thus it is the means of "interconnecting" between the groups.

7. The tens and units impulses now come in turn, setting their respective signal registers.

8. The called line is now indicated on the totalizer, so

that the idle division of the secondary connector (selected automatically by the secondary connector controller) will pick up the right line.

During the spring of 1899 the work of reshaping the apparatus to a more practical commercial form was in progress. While so doing, they made other improvements

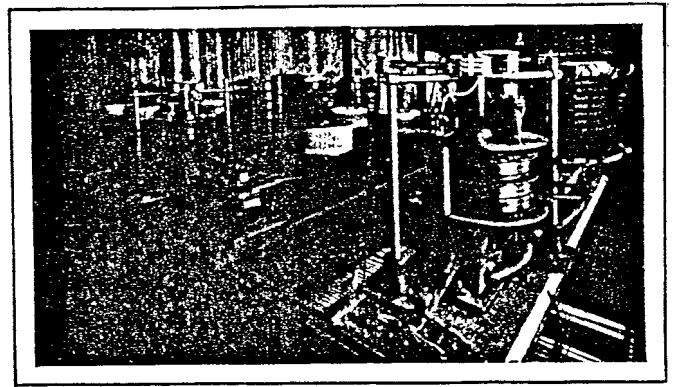


Fig. 136. Rear View of Old Lorimer Automatic Exchange.

as well. For instance, they devised a signal transmitter controller, so that the signal receiving apparatus at central was not set by impulses generated at the sub-station, but caused to stop at a certain contact as pointed out by the sub-station. The interesting details of this will be given later.

Fig. 137 shows this apparatus, forming the next step in

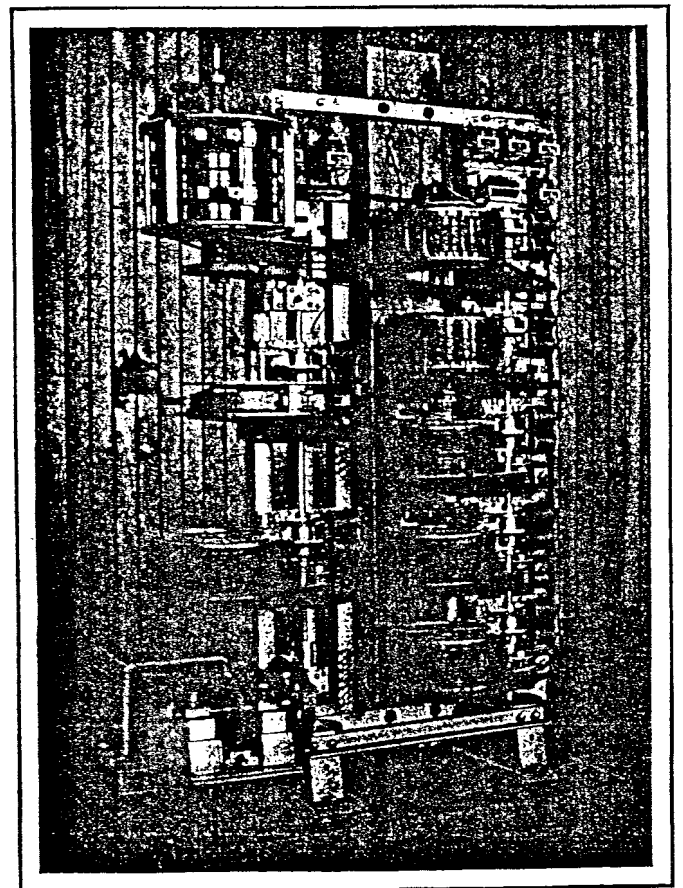


Fig. 137. The Remodeled Lorimer Automatic Exchange.

the development, completed in December, 1899. It will be noted that the form has been materially changed. The three pieces of apparatus at the left are the decimal indicator (formerly called preliminary impulse receiver), the transmitter controller, and the division starter, all common to a section of 100 lines. At the right, in a vertical column, are the primary connector, rotary switch, interconnector, secondary connector, etc., all individual to one division (or cord circuit). Instead of having one primary connector, with ten large discs inside, one for each division,

there is one separate primary connector for each division. The former bank of contacts was a cylinder sixteen inches high and the same in diameter. In this it is only about eight inches high, and the same in diameter. The contacts have been reduced from 3,000 to about 300. The circuits of this exchange will not be discussed here, as they are sufficiently like the completed exchange not to warrant repetition. This form was so nearly a realization of Mr. Neill's ideas of a practical exchange that he and Hoyt Lorimer went to New York to seek legal aid in patenting the invention. Application for patent was made April 24, 1900, with Mr. H. C. Townsend as attorney.

Since Mr. Romaine Callender had not been connected with the company for a number of years, many of the stockholders objected to the continuance of his name. So on March 14, 1900, the name was changed to the American Machine Telephone Co., with George W. Lorimer as secretary-treasurer.

Preparations were started to manufacture the system on a more extensive scale. Jigs, templets, dies, special tools, etc., were made in duplicate for the United States and Canadian companies, and considerable activity displayed. A system was installed at Peterboro, Canada, which is still in successful operation. The system was made common battery, talking as well as signaling. An exhibit board was sent to Paris, France, with George Lorimer in attendance, and successfully demonstrated before a large group of engineers. All wires were run in the open, and the committee, taking the keys of the apartments, made a most minute examination to assure themselves that all was fair.

Test after test was applied with the utmost rigor, until practically all were satisfied. But one gentleman lingered after the rest, coming day after day to study it. At last he struck a new line of attack and indicated through an interpreter that he thought only certain lines in the boards were wired to operate, more than that few being incapable of operation. Now, although the exchange was designed and equipped for 200 lines, only a few had been tested out for crosses and opens. About a dozen had been tested clear, and connected to telephones at different locations in the apartments. Being unable to convince this obdurate man, Mr. Lorimer in desperation gave the terminals of a telephone into his hands and said, "Connect anywhere." So he ran down through the whole 200 lines, calling all the other telephones from each. Not a call failed, and the verdict given by the Frenchman was "Perfect!"

Besides the board at Paris (Fig. 138) a public exchange of 400 lines is now working at Lyons, France, and 300 lines at Rome. A system is now (1909) being installed at Brantford, Canada. A 200 line switchboard, Fig. 139, is yet in the office of the American Machine Telephone Company, at Piqua, Ohio, this view being given for the additional light which it throws on the construction.

November 6, 1901, Hoyt Lorimer died of typhoid fever at the home of Mr. Neill. Hoyt was a young man who

threw his whole soul and power into the work, even to the neglect of his health. Nearly all of the drawings of circuits and apparatus were his work. In the development of ideas the work of the two brothers was so interwoven that the origin could not be credited to one more than the other. It was a true case of joint invention.

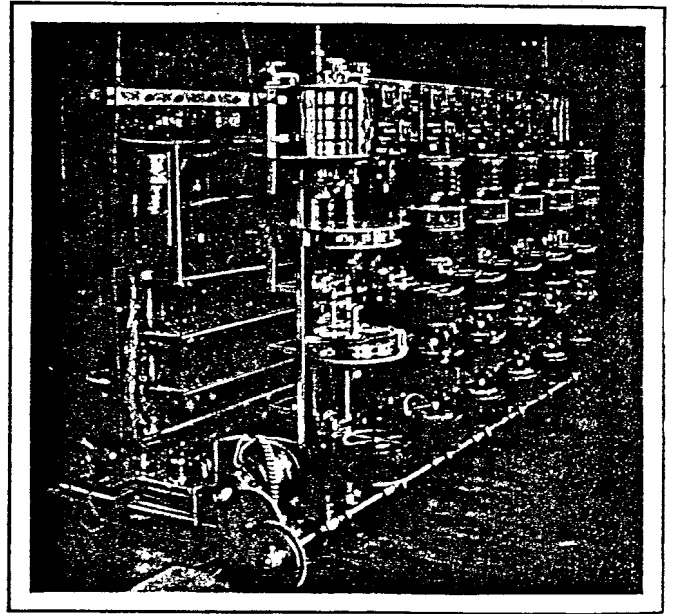


Fig. 138. The Lorimer Exchange Installed at Paris, France.

43. The completed Lorimer System

General Considerations.—The completed system worked out by the Lorimer Brothers is so different from others in plan and execution, that careful attention must be paid to the description to secure a proper understanding of its operation. Several underlying principles should be recognized at the outset. They may be catalogued as follows:

1. No apparatus at central individual to any line.
2. Power drive for all contacts.
3. Positive control of calling device at substation by central office apparatus.
4. The multiple wiper principle, which will be explained.
5. The finder switch principle.

The unit is an assembly of apparatus designed to serve 100 lines, and is illustrated by Fig. 139. It is divided into a number of groups called "divisions" (5 represented) each division corresponding to a cord circuit of a manual board.

The parts which make up one division are arranged in a vertical column, 4, 5, 6, 7, 8 and 9. They constitute a train of apparatus reaching from the calling to the called line. When a call comes in the action is very similar to that of a manual board. Like the answering plug, the primary connector, 4, hunts up the calling line and connects it. Then the intermediate apparatus receives the number. Final connection to the called line is completed by the secondary connector 9, which acts like a calling plug.

It is evident that the number of "divisions" will be fixed solely by the amount of traffic. If the number of calls increases, more divisions can be added.

The primary connector might be called a finder switch, since it finds the calling line. No two primary connectors in a 100-unit can act at the same instant, as they are controlled by the division starter, 12.

The rotary switch, 5, controls the switching and rearranging of circuits during the progress of the call, and is the general utility member. It gathers to itself the functions of all the side-switches in the Strowger system besides other duties peculiar to the Lorimer mode of working. It comprises the greatest complexity of the system, the rest being very simple. If the place and work of the rotary switch are mastered, the rest of the system will be easily understood.

The signal transmitter controller, 6, has the main duty of regulating the movements of the substation apparatus. Without its action the number set up by the subscriber will not be sent into the office. The signal transmitter controller also has to do with some of the signaling and talking circuits.

Mounted on the rotary switch is the thousands register, a device for selecting the desired thousand group. It does

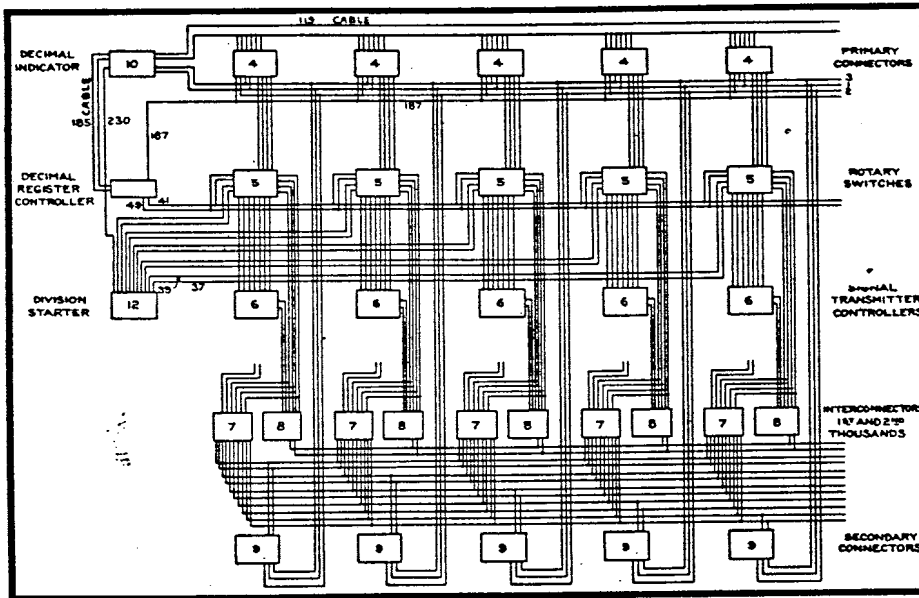


Fig. 139.—Relation of Switches in 100 Line Unit.

this by picking up either interconnector 7 or 8, according as the called number is in the first or second thousand. It is apparent that each division of apparatus will have to be equipped with as many interconnectors as there are thousands in the system.

The interconnector (7 or 8) has the duty of selecting the desired hundred group and then automatically picking out a non-busy secondary connector in that group. The interconnector has the function of a "selector switch" in other systems.

The secondary connector, 9, picks out the called line, completing the chain of connections extending from the calling line through the primary connector, rotary switch, signal transmitter controller, interconnector and secondary connector to the called line.

At the left in Fig. 139 are three pieces of apparatus which are common to all divisions of this hundred group; 10 is the decimal indicator, which periodically tests all the lines of the 100 and, if one makes a call, assists in starting the connection; 12 is the division starter, and, true to its name, it starts an idle division to hunting for the calling line.

The decimal register controller, 11, works with the decimal indicator in guiding the wipers or brushes off a primary connector to the terminals of the calling line.

The Cylinder Switch.—This is the basis of most of the apparatus. It consists of a bank of contacts completely circular in form with the contacts projecting inwardly.

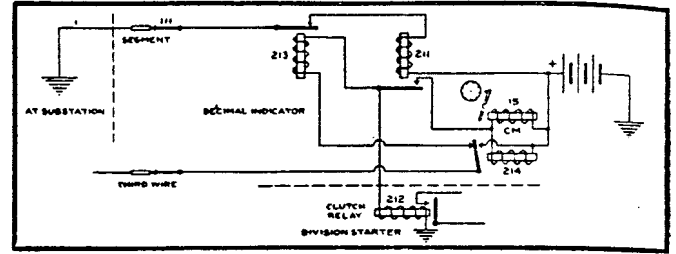


Fig. 140.—Stopping Circuit of the Decimal Indicator.

Vertically through the central space runs a shaft carrying many brushes or wipers, which ride upon these contacts. Usually there are several brushes which bear on the same level or row of contacts. The brush carrying shaft is geared to a constantly rotating power shaft, but the connection is through a clutch operated by a magnet.

Normally the magnet is de-energized, the clutch released, and a stop applied to a toothed wheel which locks the brushes in a certain position. When the magnet is energized, the lock is removed and the clutch applied so that the brushes will be rotated by the power shaft.

The Register.—This consists of several wipers bearing on a bank of about ten contacts per level. These wipers have only a rotary motion. They are driven by a spring which is normally under tension. A magnet-controlled escapement allows the spring to drive the wipers step by step, over the contacts of the register bank.

The Primary Connector.—This consists of a cylinder switch with a register mounted on top of the brush carrying member. (See Fig. 144, which is stripped of all but the essential details.) It has a clutch magnet, 19, and a relay, 118. The decimal register, 61, has a magnet, 29, to regulate the escapement motion of the wipers over the contacts.

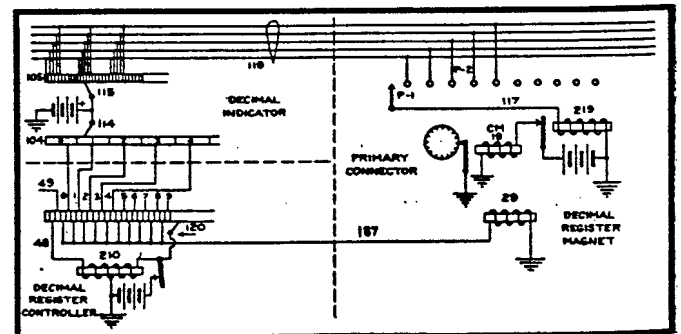


Fig. 141.—Identifying Calling Line.

There are ten sets of brushes (represented by M-1, M-2 and M-3), bearing on subscriber's line terminals. Each set of brushes is wired to a set of contacts on the regis-

ter. Moreover, each set of cylinder brushes can move over a certain ten sets of bank contacts. For instance, a certain set of three brushes will be able to move over the bank contacts of lines 0 to 9 inclusive, another set will move

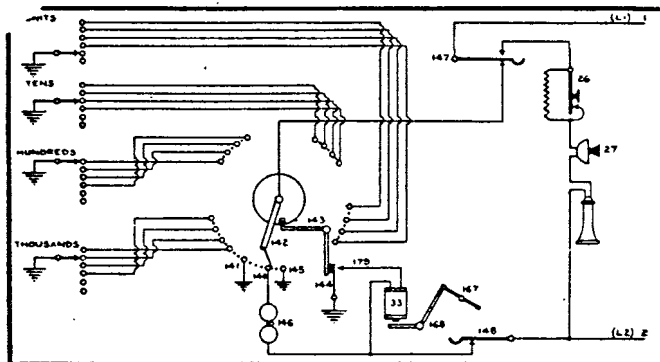


Fig. 142.—Lorimer Sub-Station.

over 10 to 19, another over 20 to 29, etc. Hence if we desire to connect with line 45 we must first move the register to connect us with that set of cylinder brushes presiding over 40 to 49, then move all the brushes six notches. Our selecting set of brushes will now be resting on 45. Other sets will be on 5, 15, 25, etc., but as the register has not connected with them no harm is done. This relation is known as the "Multiple wiper" principle and is used throughout the Lorimer system.

The Decimal Indicator.—This consists of four stationary commutators as thoroughly built as those used on motors and dynamos. Each commutator has a revolving brush which is maintained in motion day and night by a motor or other suitable power. Commutator 101 (Fig. 143), contains 100 segments, to each of which is connected the No. 1 wire of some subscriber in the 100 group. Brush 111 revolves continually over these segments hunting a calling line. When a line initiates a call this brush will stop on the segment belonging to that line, and cause an idle primary connector to hunt up the line desiring connection.

Commutator 106 has the duty of placing a busy or guarding potential on the third wire, 3, of the calling line to safeguard it against being called by another. Commutators 104 and 105 determine the identity of the calling line and will be described in detail.

Subscriber's Telephone.—This consists of a common battery talking set of any desired pattern (typified by a

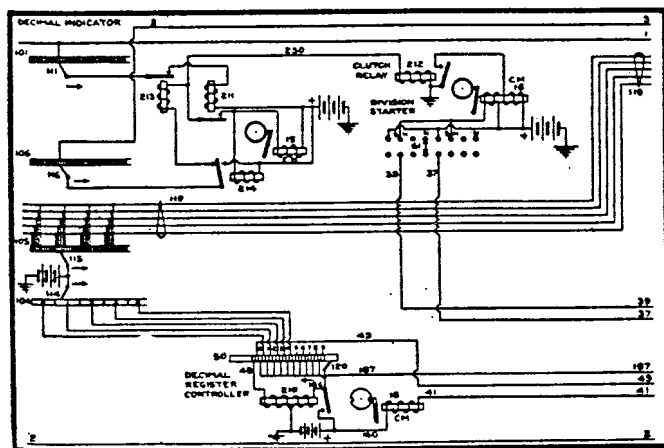


Fig. 143.—Call Detecting Apparatus.

transmitter and receiver, Fig. 142), in addition of the calling device or "Signal transmitter." A brush carrying arm, 142, is arranged to travel over a circle of contact pins, every alternate one of which is dead. Normally it rests on contact

140, connecting the bell, 146, to the line. The end of a spiral clock spring is attached to the arm 142. The other end is attached to a lever by means of which the spring 33 controls the pawl, 168, so that for every complete cycle train of gears ending in a rotary escapement 167. Magnet can be wound up. The rotation of arm 142 is regulated by a or motion of the armature to and fro the escapement will not allow the brush, 142, to advance from one contact to the next.

The contact 144-179, is closed by the act of pulling down the lever which winds up the spring. The same act advances brush, 142, to contact, 141, but further motion is prevented by escapement, 167.

At the left in Fig. 142 are shown four rows of contacts. There are ten contacts in each row. Each row represents one of the digits of the called number. A brush is adapted to be used over each row, placing a ground on any desired contact. It is these which the subscriber adjusts in setting up the number of the line with which he wishes to talk.

The hook spring has two main springs, 147 and 148, mechanically connected together. The lever of the hook switch is locked down during the call except when brush, 142, has completed its work.

Process of Making a Call.—The subscriber first sets up the number by sliding or rotating the brushes, 171, to the

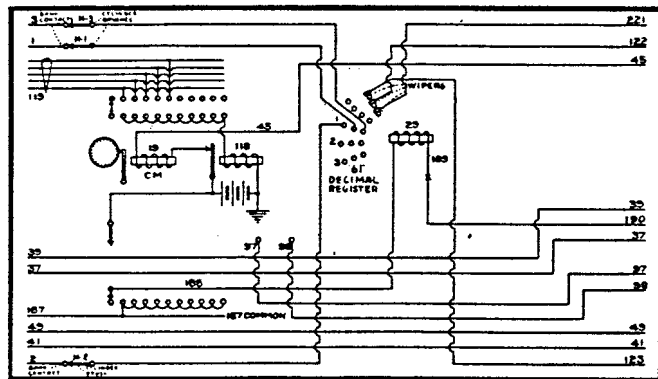


Fig. 144.—Primary Connector Circuit.

proper digits corresponding to thousands, hundreds, tens and units, respectively. He then pulls the starting lever all the way down, and thus winds the spring and advances brush, 142, to contact, 141, and locks the hook-switch down.

This places a ground on line 1, which causes the constantly rotating brushes of the decimal indicator at "Central" to stop on the segment of the calling line. The stopping circuit is given in Fig. 140, all non-essentials being omitted.

When brush 111 strikes the grounded segment, relay, 211, energizes. This closes a circuit through the clutch magnet 15, which stops the revolving parts. Relay 214, in parallel with the clutch magnet, also pulls up, putting positive battery on the third wire of the calling subscriber's line, this being the busy or guarding potential.

It will be noted that negative battery is connected to earth, contrary to the usual custom, although this reversal of polarity has nothing to do with the normal operation of the system.

The clutch relay, 212, of the division starter (in series with 15 and 214) also pulls up, thereby causing the division starter to move and act on an idle division. This action comes about by brush 61 of the division starter (Fig. 143) sending an impulse from positive battery over wire 37 to clutch magnet 17 of the rotary switch (Fig. 145) moving the cylinder brushes of the latter from their normal *N* at top of drawing to the first *I* position.*

Identifying Calling Line.—In Fig. 141 the scheme of identification is given most simply. A cable, 119, of ten wires runs from commutator 105 to each primary connector. The wires are multiplied to a certain row in each cylinder. The

Brush 120 now carries positive battery potential so that for the rest of its journey it will send impulses over the wire, 187 to the decimal register magnet 29 on the primary connector. This advances the register brushes to connection

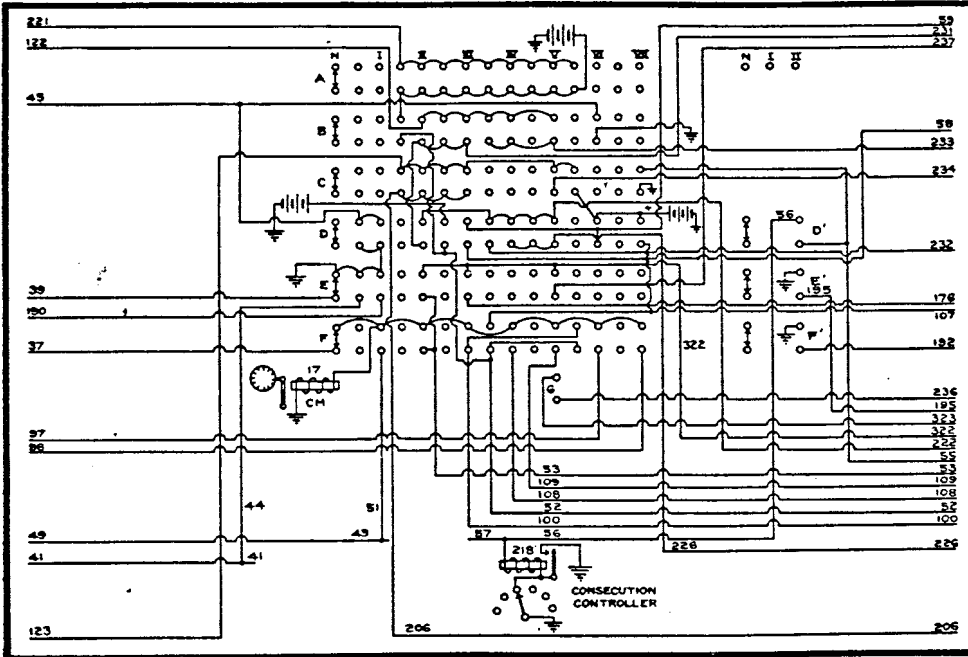


Fig. 145.—Rotary Switch.

The rotary switch bank contacts are shown as if the inside cylindrical surface were rolled out flat, each circle representing a contact. The double pointed arrows indicate brushes which bridge together two rows of contacts. The rotary switch by this motion starts the primary connector cylinder brushes by clutch magnet 19 and the decimal register controller by clutch magnet 18.

Brush 120 now carries positive battery potential so that for the rest of its journey it will send impulses over the wire, 187 to the decimal register magnet 29 on the primary connector. This advances the register brushes to connection with that set of cylinder brushes which represent the tens digit of the calling line. When contact 48 of the decimal register brush 120 puts both windings of relay 210 in parallel, so that they neutralize each other and the armature falls back. Thus by two separate operations carried on at the same time the working wires of the division are carried through and connected to the calling line.

The last act of the decimal register controller energizes clutch magnet 17 of the rotary switch (wire 49, 51 contact FI Figs. 143, 144 and 145), sending it on to its second top, position II.

Receiving Signals.—This motion of the rotary switch shifts the connection and starts the signal transmitter controller to receiving the first two digits, thousands and hundreds. It is here that the peculiarity of the Lorimer method

segments, 105, of the decimal indicator are divided into ten groups of ten each, and the wires of cable 119 multiplied as shown. These are to indicate the units. Brush 115, bearing positive battery, has stopped on a segment corresponding to the units digit of the calling line. Cylinder brush P-1 of the primary connector is in line with the regular brushes. As they revolve, due to clutch magnet 19 being energized, P-1 will in course of time strike the contact made live by brush 115 of the decimal indicator. This causes relay 219 to pull up, cutting off clutch magnet 19 stopping the cylinder brushes on the units digit of the calling line.

Commutator 104 is divided into ten large segments, each occupying the space of ten segments of 105, with which they are in exact line. Brush 114, carrying battery, has stopped on that segment corresponding to the tens digit of the calling line, and therefore makes live a certain segment of the decimal register controller. Its brush, 120, has been started on its rotation; as it passes over the segment nothing happens until it strikes the segment made live by brush 114. This energizes relay 210, which at once locks up with current through its own contact.

of transmitting signals becomes evident. For the purpose of making the positive control of the sub-station apparatus more clear Fig. 149 has been prepared. At the sub-station, of the contact pins over which brush 142 moves, only a

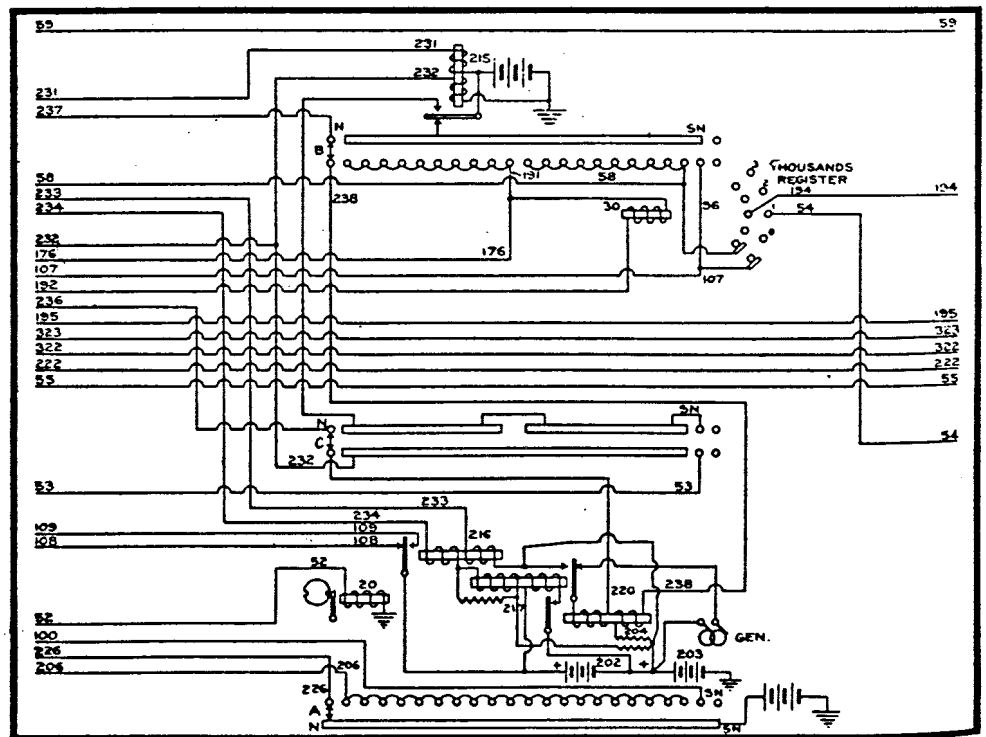


Fig. 146.—Signal Transmitter Controller.

portion are shown, and only one of the four digits indicating brushes, G. At "Central" that part of the signal trans-

mitter controller concerned is represented by three wipers, *A*, *B* and *C* and relay 215. The escapement magnet at the right may be any of those used to advance wipers corresponding to any digit of the called number.

Wipers *A*, *B*, *C* are attached to the same shaft, and move exactly together. *A* transmits a series of impulses over line *L-2* to escapement magnet wiper 33, the latter advancing arm 142 step by step over the contact pins. Wiper *B* sends a similar series of impulses to the escapement magnet in the exchange, setting forward the wipers which it controls. Wiper *B* strikes each of its contacts just a little after *A* has touched its own corresponding contact.

When the signal transmitter controller, at the proper time, has been started, wiper *A*, acting over line *L-2* and magnet 33 steps arm 142 over the contacts at the substation. Simultaneously the escapement magnet at "Central" has been stepping its own mechanism along by impulses received from *B*. In course of time arm 142 strikes the pin grounded by brush *G*. At once relay 215 is energized, cutting off battery from the escapement magnet at "Central." It and its mechanism are therefore stopped at the position indicated by the position of brush *G* of the substation. Relay 215 is locked up by its front contact and wiper *C*. However, when the latter reaches the end of its continuous segment the locking circuit is broken and the whole arrangement of circuits is changed.

Referring again to the main series of detail circuits, (Fig. 146 in particular) the brushes of the signal transmitter controller make their revolution in accordance with the following code:

- First—From normal *N* to subnormal *SN* receiving thousands and hundreds digits.
- Second—From subnormal *SN* to subnormal, a complete revolution, to receive tens and units digits.
- Third—From *SN* to *N* a short step connecting up the talking circuit.

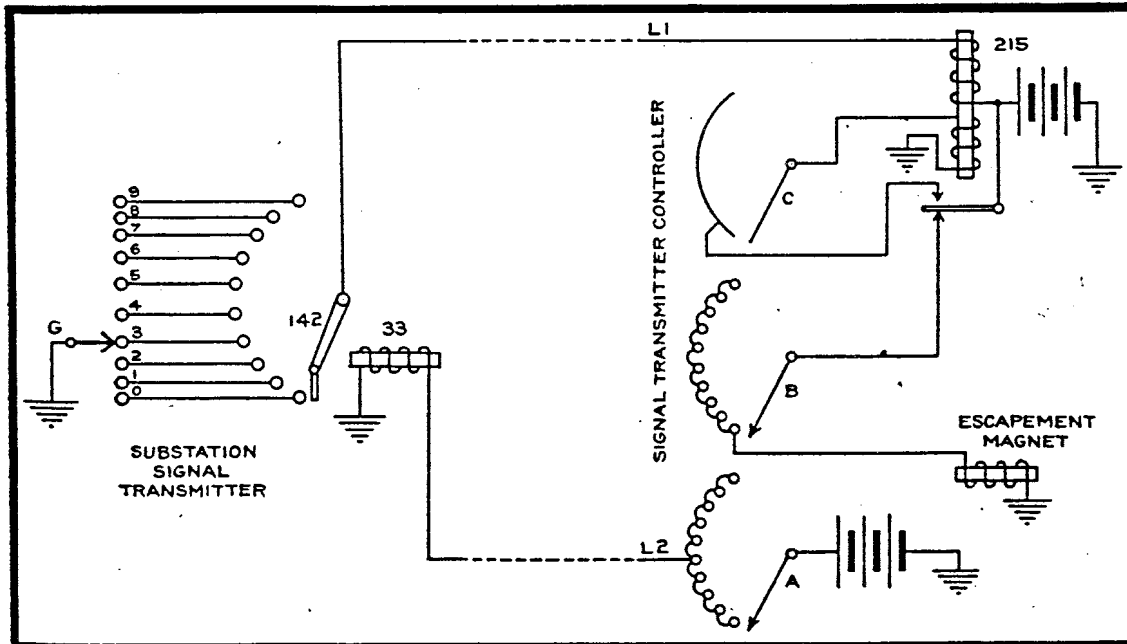


Fig. 149.—Control of Signal Transmitter.

This action is secured by having a notched disc geared to the cylinder brush shaft, so that the disc will make one revolution while the cylinder brushes make two. In the edge of the disc are cut notches so that the dog on the clutch lever will stop the brushes at the positions indicated.

Automatic Trunking.—The proper thousand and hundred having been selected, the next step is the picking out of an idle secondary connector in the called group. An idle condition is indicated by a ground on wire 224, (Fig. 147), while if busy that wire will be alive with positive battery.

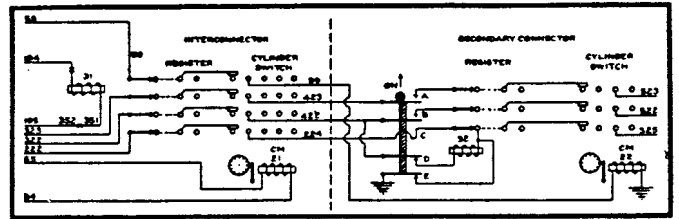


Fig. 147.—Interconnector and Secondary Connector.

When relay 215 fell back from its last work it started the cylinder brushes of the interconnector over the following circuit (Fig. 146): *SN* of *B* wiper, wire 96, outside brush of thousands register, wire 54, clutch magnet 21, (Fig. 147) wire 55 contact *D* of rotary switch, (Fig. 145) wire 56, relay 218, to consecution controller and ground. The consecution controller is a constantly rotating wiper which is intended to prevent two interconnectors from seizing the same instant. It does this by giving ground to each in succession so that one will always be a little in the lead of the other.

As the cylinder brushes of the interconnector rotate to find a non-busy secondary connector, a testing circuit in the former tries each trunk passed. This testing circuit is as follows: Positive battery upper coil of relay 215, (Fig. 146) wire 231, contact *D-II* of rotary switch wire 222 to inner brush of register on interconnector (Fig. 147), thence to bottom cylinder brush. When this brush strikes the first idle trunk, the ground at *E* of the secondary connector energizes relay 215 of the signal transmitter controller (Fig. 146) breaking its back contact and releasing the clutch magnet 21 of the interconnector (Fig. 147), thereby stopping the cylinder brushes. The front contact of 215 starts the rotary switch from position 11 to 111. This motion of the rotary switch starts the signal transmitter controller to receiving tens and units digits, setting the tens register and cylinder brushes of the secondary connector over circuits which are easily traced.

The cylinder brushes of the secondary connector are now

resting on the terminals of the called line.

Busy Test of Called Line.—The condition which indicates that the called line is busy is positive battery on the private contact or third wire (325, Fig. 147) while a ground or open indicates that the line is disengaged.

While the rotary switch is moving from position III to position IV, it makes a momentary contact (at *D*) which closes the testing circuit to determine whether the called line is busy or free. This circuit is as follows: ground, lower coil relay 215, wire 232, rotary switch D-III½, wire 222 through the interconnector wipers, wire 224, to the private wiper of the secondary connector.

At the same instant that the above test circuit is closed, the rotary switch also closes a circuit to energize the clutch magnet, 20, of the signal transmitter controller. This circuit involves the back contact of relay 215.

Now, if the called line is busy, the test circuit mentioned above will cause the relay 215 to pull up, preventing the signal transmitter controller from moving. This keeps the called line clear of connections. But if the called line is free, the relay 215 will not be energized and the signal transmitter controller will be moved from position *SN* a short step to position *N*.

In this position the signal transmitter controller puts positive battery on the private wiper of the secondary connector, to protect the called line. It also makes the necessary connections from the repeating coil and battery to the line brushes resting on the called line to feed battery current for talking.

Ring and Talking.—The calling subscriber now lifts his receiver from the hook, thereby de-energizing relay 216, which has been held up over line 1 and the ground at the substation. As relay 216 falls back it gives positive battery to the clutch magnet 17 of the rotary switch (Fig. 145) moving the latter to position *V*.

The rotary switch is now in the talking position and the two telephones are connected over a circuit which is shown, simplified, in Fig. 148.

The common battery talking set of the calling station is fed with current through relays 216 and 217. The former

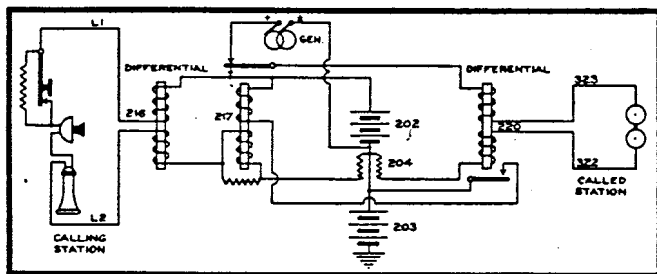


Fig. 148.—Simplified Ringing and Talking Circuit.

is differential, with windings opposing so that it offers little opposition to talking current. The winding of relay 217 which is used is shunted with non-inductive resistance for the same purpose. Relay 216 is solely for release purposes. Relay 217 is the ringing relay. The calling subscriber, with his receiver at his ear, presses the ringing button. This inserts a high resistance in the line, so that relay 217 falls back. This projects ringing current on the called line. It will be observed that it must flow through the called half of the repeating coil. This induces a flutter in the calling subscriber's receiver, which is his indication of a successful connection. If the line had been busy, the circuit of Fig. 148 would not have been established, and on attempting to ring no flutter would result, which would indicate a busy line. When the called subscriber answers, conversation is carried on by the well-known Hayes system of common battery transmission. Relay 220 in the called loop is differentially wound with opposing coils and offers little impedance. It is to prevent the possibility of ringing on a subscriber who is just initiating a call.

Though Figs. 146 and 148 show but two windings in the repeating coil, in practice four are used, this being neces-

sary to secure a quiet line. In fact, it has been proposed to use the condenser-retardation system as installed by newer all Independent telephone companies in manually operated boards.

Release.—When the calling subscriber hangs up it restores the ground on line 1, energizing one coil of relay 216. On pulling up it energizes the clutch magnet 17 of the rotary switch, moving it to position VI. By a neatly arranged series of inter-actions between the rotary switch and the signal transmitter controller, all switches are now automatically rotated forward to their normal positions. The registers are each reset, being forced back to zero by a lug which is engaged by the escapement sector as the register moves around bodily with the cylinder brushes.

44. Lorimer Summary

Summary.—In conclusion, the following facts may be noted regarding the Lorimer system:

1. It is designed along lines of rigid control, there being no freely moving dial nor fast and slow acting relays.

2. The sub-station apparatus is practically "fool-proof," the user being unable to tamper with the apparatus until the selection has been completed.

3. All parts of the apparatus are exceedingly well made. There is nothing flimsy about any of the Lorimer apparatus which I have examined. The mechanical parts are of ample size and finely fitted. The cylinder brushes and register wipers work under sufficient pressure to make contact certain, while the power drive is a means of assuring certainty of action.

4. The electrical complication used to secure the positive control and power drive seems bewildering at first, but as the details are studied, the circuits and combinations seem more simple.

5. The negative busy signal seems awkward at first, but should not prove a serious objection. In fact, it might be considered an advantage to have the user "hear" the ringing current on its way to the bell, according to a plan which is in successful use in some places.

6. The idea of reducing central office investment to a traffic basis is a good one. It enables a reduction in first cost, if the connecting apparatus be simple enough, and gives greater time efficiency. In a system employing a separate switch for each line, at the busiest hour of the day 90 per cent or more are idle, while for the 24 hours the average will be about 98 per cent idle. In the Lorimer system the only parts of the central office equipment which are individual to each line are the cylinder switch contacts in primary and secondary connectors and the segments of the decimal indicator.

7. While the user is setting up the number on his signal transmitter, or calling device, and pulling the lever which sends the preliminary impulse, the central office apparatus has done nothing for his call. While the switches are taking care of his call the user must wait, if even for a short time. This is an inevitable result of the absolutely controlled feature mentioned under (1). A free dial allows the switches to be working while the dial is rotating back, so that when the user gets through with his manipulations the connection has been completed. There is no wait. However, the actual difference in seconds is not great.

8. As illustrated, no automatic selection of an idle trunk to a thousand group is shown. This would require as many interconnectors in each division as there are thousands in the system. In a 10,000 system, with full 10 per cent switching, this would mean 10,000 interconnectors, alone. It has been proposed to use another interconnector to avoid this trouble.

The Lorimer system is being used in exchanges serving the public at Peterboro and Brantford, Canada, where it is giving excellent satisfaction.