BELL LABORATORIES RECORD

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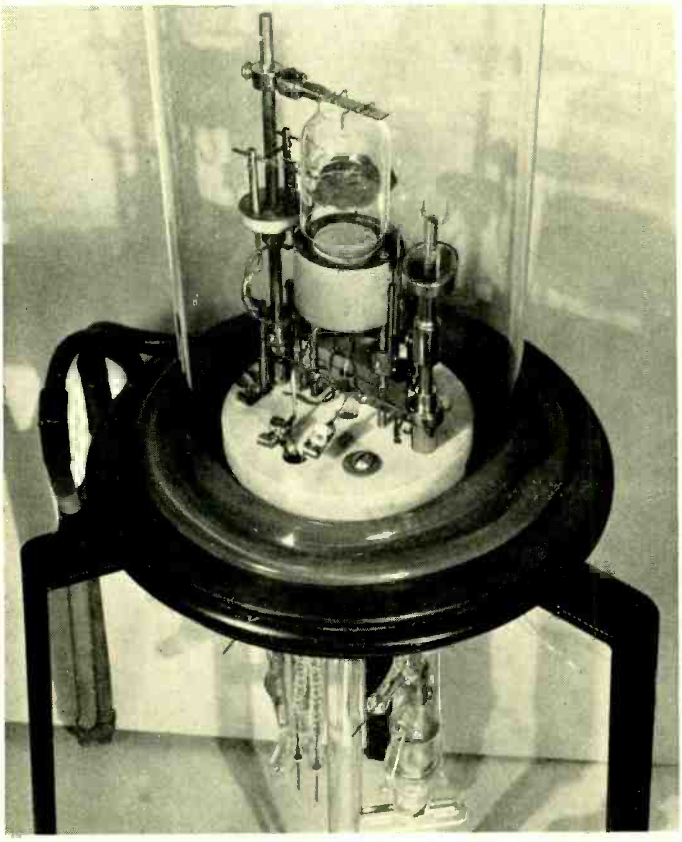

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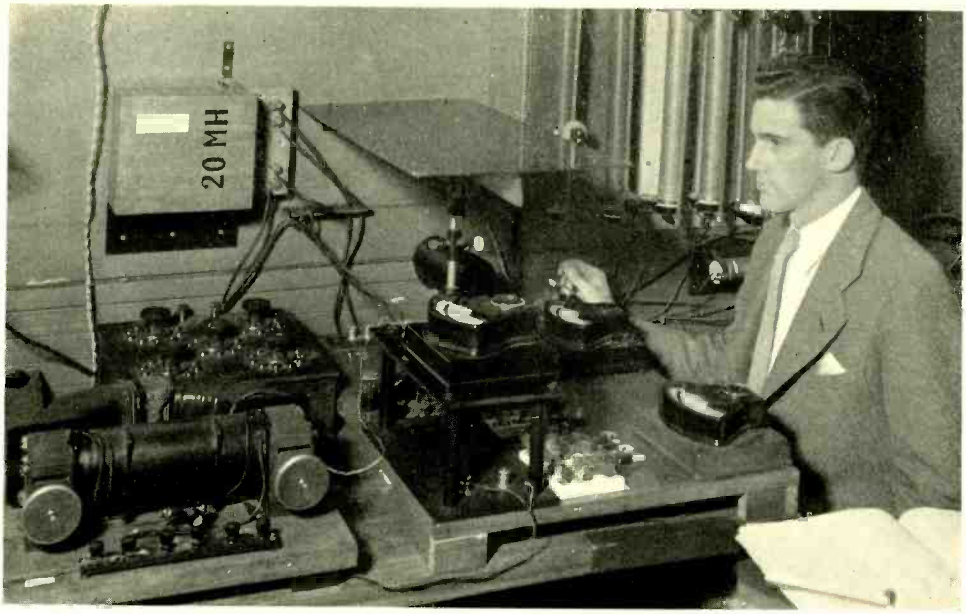


Permanent Magnets

By R. A. CHEGWIDDEN
Telephone Apparatus Development

PERMANENT magnets have been important elements of telephone apparatus ever since Bell and Watson generated a talking current by means of an iron diaphragm, a few turns of copper wire, and a permanent magnet. Although the modern telephone bears little resemblance to Bell's crude equipment, one of the essential elements of the latest receiver is still a permanent magnet. Many other pieces of apparatus, such as polarized relays, ringers, coin collectors, loud speaking receivers, light valves, and reproducers depend upon the properties of permanent magnets to perform their particular functions.

An ancient legend tells us that the first permanent magnet was discovered approximately in the year 800 B.C. by a Cretan shepherd who became curious as to why his iron studded sandals were attracted to the earth at one particular spot. The stone which he uncovered was a natural magnet, a piece of magnetite or loadstone as it was then called. Many were the tales of the astounding properties of loadstones; one of these was of the existence of a mysterious mountain of loadstone so powerful that ships built with iron nails were pulled apart as they approached it. The word magnet is supposed to have been derived from Magnesia, the name of a district in Asia Minor from which loadstones were obtained in considerable quantities.

Some use was made of the loadstone in the form of crude compasses but little was known of the actual laws of magnetism until the year 1600 when William Gilbert published his observations on the behavior of magnets.

Since that time, other investigators have gradually widened our knowledge of those laws and devised the present day theories of magnetism. It would seem that everything should be known of so ancient and apparently so simple a thing as a permanent magnet, but, as with many other apparently simple things, the simplicity hides a complicated structure whose exact nature is still a mystery.

In general, the behavior of the magnet may be explained by the commonly accepted theory which assumes that all magnetic material contains myriads of tiny systems, sometimes called magnetons, which have the properties of miniature permanent magnets. To demonstrate the plausibility of this theory, Ewing once built a model of a magnet by mounting a large number of small compass needle magnets side by side on a board. This artificial magnet exhibited many of the characteristics of real magnets. It showed, among other things, that the magnetic field of a permanent magnet, i.e. the region around a magnet where its action may be detected, could be explained as being the result of the summation of the magnetic forces of the little unit magnets.

Magnets may be divided into two general classes, electromagnets and permanent magnets. Electromagnets must be energized continuously by a coil of wire carrying an electric current to produce magnetic fields, and they easily become demagnetized after the magnetizing force has been removed. Permanent magnets on the other hand are capable of producing magnetic fields by themselves, and they resist demagnetization. With reference to Ewing's model, electromagnets may be represented by a board containing compass needles which may turn about their axes freely; permanent magnets may be represented by the same board but with the needle magnets surrounded by fine particles of loosely packed sand so that the needles would be much more difficult to move. With the latter condition it would require a stronger magnetizing force to compel the needles to line up in the same direction, but, once in alignment, the needles would have a greater tendency to stay in that position; in other words, the model would be more difficult to demagnetize.

Unless a permanent magnet can retain the major portion of its magnetism after being subjected to

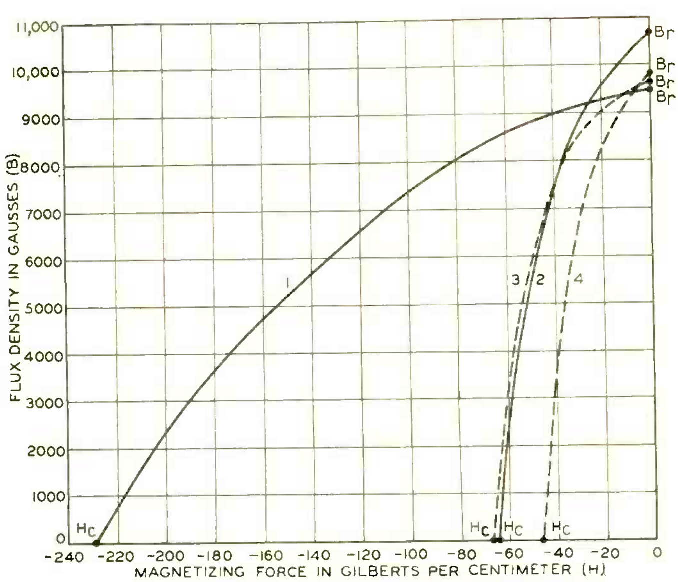


Fig. 1—Characteristic curves of typical magnet steels: 1—cobalt steel, 2—tungsten steel, 3—high chrome steel, and 4—low chrome steel

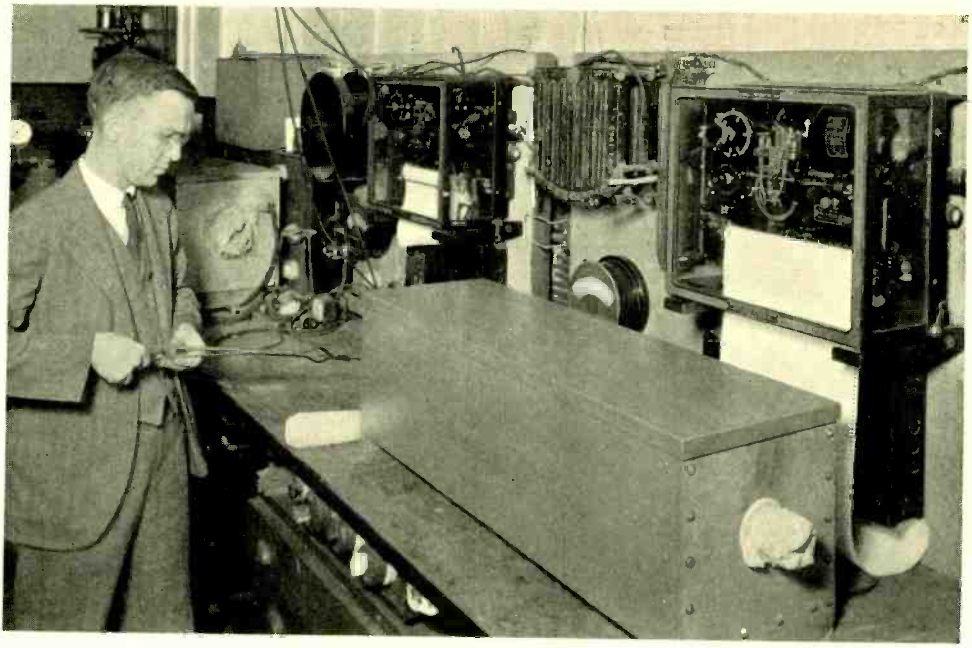


Fig. 2—Electric furnace with temperature control employed in the Laboratories for heat treating magnet steels

moderate demagnetizing forces, it is not of much value as a magnet; neither is it valuable if it cannot produce a magnetic field of fairly high intensity. The magnetic characteristics of the steel of which the magnet is made determine how well the finished magnet will do these things. Magnetic flux is to the magnetic circuit what electric current is to the electrical circuit, and the ability of a magnet to attract and hold pieces of magnetic material is directly proportional to the density of the magnetic flux in the magnet.

To determine the magnetic characteristics of a piece of magnet steel, a number of values of the magnetic flux density in the steel are plotted against the values of magnetizing force required to produce them, as the magnetizing force is varied from zero to a maximum first in a positive, then in a negative direction, and so on back to zero. The resultant curve drawn through the plotted points will be a magnetic hysteresis loop such as was described in an earlier issue of the Record*. The portion of the hysteresis loop in the upper left-hand quadrant is sometimes called the demagnetization curve of the material, and is of particular interest in the design of permanent magnets. Such demagnetization curves are given for a number of magnet steels in Figure 1, and the laboratory set-up for securing the information is shown in the photograph at the head of this article.

The intercept with the horizontal axis indicates the value of the coercive force, H_c, which is a measure of the ability of the steel to resist demagnetization. The higher the value of coercive force, the greater is the resistance to demagnetization and vice versa. The intercept with the vertical axis gives the residual induction, B_r, the density of the magnetic flux re-

*Record, *March*, 1932.

maining in the steel after magnetization. The magnetic flux density in a bar magnet is usually lower than the B_r of the steel because the ends of the magnet exert a demagnetizing force upon the rest of the bar. This so-called demagnetizing effect of the ends is greater in bars whose ratio of length to cross-section is small. In very long and thin magnets, the end effect is negligible. A knowledge of the coercive force of the material is of value when estimating the relative magnetic strengths of short magnets of the same size but of different materials. When the coercive force is very high, as it is in cobalt magnet steel, short magnets may be made which will have as high magnetic strength as considerably longer magnets made of a material whose coercive force is lower. On the other hand, the relative strength of long thin magnets is dependent primarily on the residual induction of the material used. Long, slender magnets are capable of greater magnetic strength when made of tungsten steel rather than of any other common steel because the residual induction of tungsten magnet steel is relatively high. Well designed commercial magnets have values of flux density in the neutral or middle region which are about two-thirds that of the residual induction of the steel.

All the commonly used magnet steels are virtually carbon steel with certain percentages of other elements added. This material is the oldest commercial permanent magnet steel. The ability of carbon steel to resist demagnetization is dependent to a large degree on the amount of carbon in the steel and on the heat treatment the steel receives. The best permanent magnets probably are those which are cast and hardened without being subjected to any intermediate hot rolling or hot forming operations, although data taken on cast specimens do not always show this fact, due primarily to our inability to produce dense, homogeneous castings. The combination of elements responsible for good magnet steel seems to be disintegrated gradually by repeated heat treatment at elevated temperatures until, if the heat treatments are continued, the steel finally becomes entirely unsuited for use in permanent magnets. It is necessary then to recombine the elements in the steel by reheating at a temperature close to the melting point or by actually remelting it. It is therefore desirable to carry

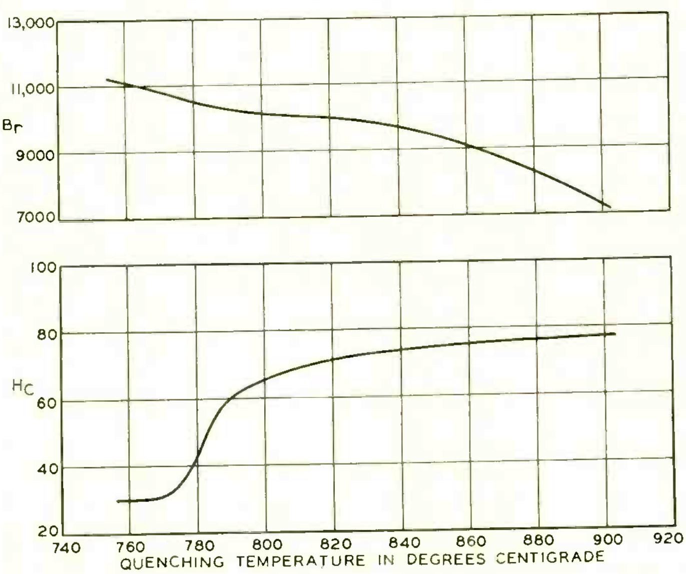


Fig. 3—Variation of residual induction (B_r) and coercive force (H_c) of high chrome steel when quenched in oil from various temperatures

out the heat treating process in as short a time as possible to minimize this "spoiling" of the steel.

All magnet steels containing carbon must be cooled quickly from some point above a certain critical temperature so that they may have the structure most suitable for permanent magnets; this is usually accomplished by quenching in oil or water. Whenever there are two or more characteristics desired in anything, it is seldom possible to obtain the combination in which all are at a maximum, and so it is with permanent magnet steels: the heat treatment most favorable for the production of the highest coercive force is not suitable for the production of the highest residual induction and vice versa. A compromise heat treatment, therefore, must be specified so that the finished magnets will have the highest magnetic strength after magnetization. The variation of B_r and H_c with quenching temperature is given in Figure 3 for a sample lot of high chrome magnet steel.

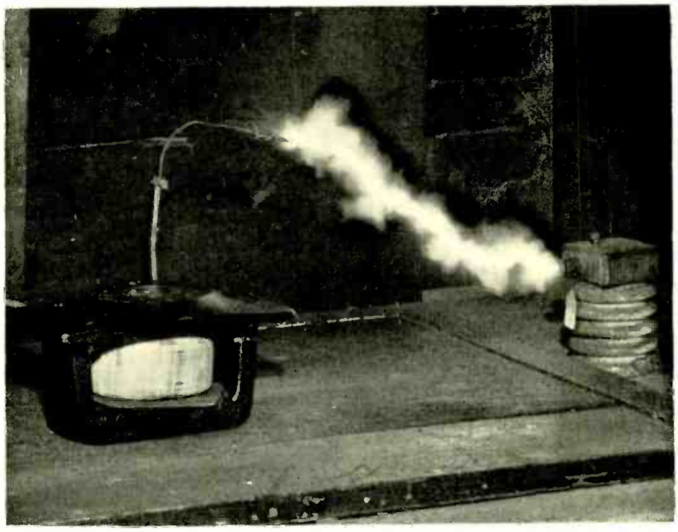
The changes which occur in the structure of magnet steel during the quenching operation are not completed immediately after the heat treatment, but will continue with diminishing intensity for some time afterward, even when the steel is at room temperature. Evidence of these changes may be detected in magnets even days after the hardening period. Steel magnetized during this period will not retain its magnetism as well as when magnetized after the internal structural changes are completed. After the structure of the steel becomes stable, however, permanent magnets will retain the major portion of their original magnetism indefinitely unless subjected to severe mechanical jars, high temperatures, or strong external demagnetizing forces.

Permanent magnets are used in telephone apparatus instead of electromagnets for a number of reasons; chief among these is, of course, the absence of the necessity for supplying magnetizing current for the field; other reasons include the lack of heating troubles, and the simplicity of design. Electromagnets, however, are more generally used when fields of very high strength are desired, because the cost and weight of the permanent magnet is then usually an important factor. The type of steel to be used in a permanent magnet is determined by the permissible size of the magnet, the magnetic properties of the steel, and its cost. Cheaper steels of comparatively low coercive force may be used in some cases where the size and weight of the magnet is not important because it is often possible to compensate for a lower coercive force by increasing the length of the magnet.

To obtain the maximum strength, magnets, theoretically, should be magnetized with a force sufficient to completely magnetize the steel; practically, it has been found that satisfactory results are obtained with common magnet steels when they are magnetized with a force of approximately five times the value of the coercive force of the steel. Most permanent magnets used in telephone apparatus are magnetized between the poles of an electromagnet, but there are some magnets so designed that it is not practical to magnetize them in that manner; such magnets have been magnetized by blowing a fuse in series with a few turns of copper wound around them, as shown in the photograph at the foot of this article. The fuse is blown by connecting the magnetizing assembly across a bank of storage batteries which may be connected to give voltages from 90 to

2200 volts. Large momentary currents are possible by this method, and, with even a few turns, the instantaneous magnetizing forces are very high.

There is still much to be learned of the nature of permanent magnet materials, and investigations now under way in these Laboratories will undoubtedly lead to better and cheaper magnets for telephone apparatus.



Blowing a fuse in the process of magnetizing a special type of permanent magnet

First Aid Kits and Facts

By W. H. S. YOURY
Outside Plant Development

JUST as a stitch in time saves nine, so does prompt first-aid action often prevent serious after-effects of injuries. In spite of substantial reductions in the rate of accidents in the Bell System as a result of safety practice measures, it is still necessary occasionally to sterilize cuts or wounds, to treat burns, to put splints on a broken leg, or to administer stimulating inhalants, in case of electrical shock or asphyxiation. First aid materials are thus provided for minimizing the seriousness of accidents when they do occur, either by providing for the treatment of minor accidents, or —for more serious accidents—by providing temporary relief until the physician, who should be called immediately, can be consulted on the case.

In the Bell System, the Medical Director prescribes the formulas and first aid treatments to be used. The development engineers specify how the materials shall be packaged and labelled to meet the requirements of the telephone plant. In specifying the variety and quantity of material provided, the kinds of accidents most frequently encountered with various types of work and the number of people that must be provided for are both considered. Thus, for a man working alone on certain kinds of jobs a kit approximately the size of an ordinary deck of playing cards, so as to fit conveniently in a man's pocket, should be available; whereas a big family medicine cabinet can be used more advantageously in a central office to provide first aid not only for a larger number of people but for a greater variety of afflictions.

A telephone man whose job takes him out with a crew of three or four others on a big truck, knows he will find first aid materials in a box that is kept in a certain place in the truck. This is the "B", or big box: a metal case some nine inches long, seven wide, and four deep. A waterproofed canvas bag is available for hanging this kit in the immediate vicinity of the men when their work takes them to some considerable distance from the truck. The man who works with one or two others on a small truck, on the other hand, has his first aid materials available in an "M", or middle-sized kit which is about half the size of the big box, and which also has its definite place on the car. The kit of the lone worker is known as the "S", or small-sized box. All three of these boxes are of a sturdy sheet metal construction.

The small S box contains only the most used first-aid materials—iodine swabs for sterilizing minor wounds, 1 inch and 2 inch compresses for protecting such wounds, carbolated petrolatum for burns, and ammonia inhalants for use in case of asphyxiation, electric shock, or drowning.

The M box, designed for light construction and maintenance crews, carries some additional compresses and bandages. It also provides, where field requirements warrant it, tubes of petroleum jelly which may be rubbed on a lineman's arms to prevent creosote burns as well as a preparation for use if needed to wash creosote off the skin.

The B box, which is the largest used in the outside telephone plant and designed for the heavy construction crews, is still more completely stocked. It carries all of the items of the smaller boxes, but mostly in larger quantities, and also a tourniquet, wire splints, scissors, and tweezers.

A central office emergency wall cabinet of a sturdy sheet metal construction is available for inside plant or central office use. This contains, in addition to the most commonly used materials of the portable kits, several other items that might be found in the well-stocked family medicine cabinet. These include relief remedies for minor ailments, such as colds, sore throat, indigestion, stomach and head pains, sprains, etc., as well as other often used items such as absorbent cotton, adhesive tape, and a hot water bottle.

Whatever the size, the box or cabinet must have a fixed place for every

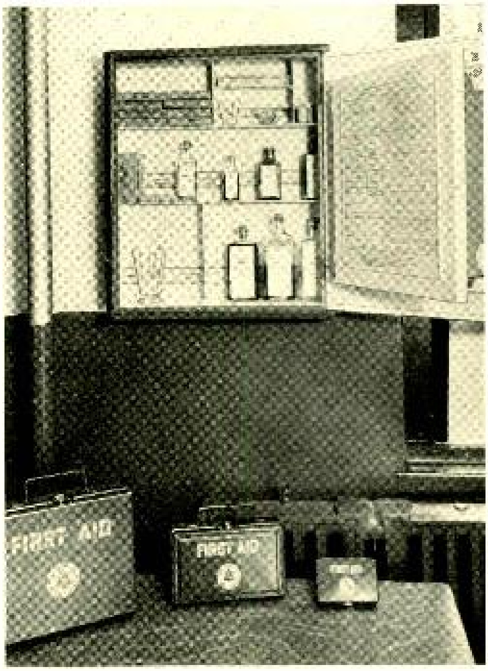


Fig. 1—First aid kits for the Bell System are put up in four sizes: the central office wall cabinet (above), the "B" or big size (left), the "M" or middle size, and the "S" or small size (right)

material so that it can be quickly found, and the directions for the use of each material must be so plainly displayed that they can be quickly understood. Every kit or wall cabinet carries a diagram or instructions designating the proper location of each item. Nearly every first aid package in the boxes has printed on it illustrated directions for using the material inside.

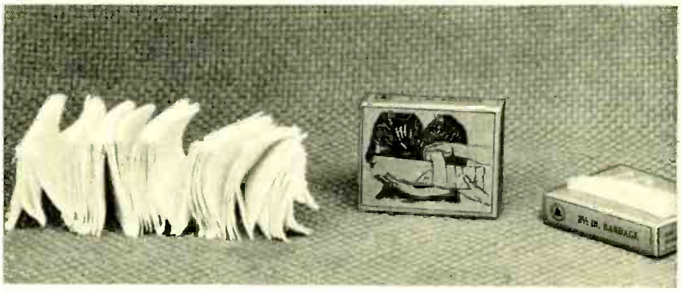


Fig. 2—Within the kits are containers, each including the maximum possible amount of some one item arranged for convenient and economic use

A scheme followed to make all the first aid packages just fit into their allotted spaces in a box is to put up all of the items in packages of the same size, and to design the box to hold just a certain number of these unit sized packages. These small packages, which are made of chipboard, are known as "D" containers, and are approximately 4″ x 2″ x ¾″. The B box is made to hold just twenty, and the M box ten of these units. Each D container is filled with as many specimens of some one material as it will carry—one, in the case of a bulky thing like a tourniquet, and as many as ten for things as small as an ampoule filled with tincture of iodine, or even twenty items in the case of 1″ compresses. This scheme simplifies future changes in the contents of a box—one package may be taken out and a substitute of the same size put in its place.

Numerous problems arise in determining the packaging of first aid materials so that they will not deteriorate, and so they will be convenient to use. For example, the 1 inch and 2½ inch gauze bandages need to be packaged so that any required amount can be removed from the original six-yard length without handling or losing what is left. This is done by folding the bandage in pleats, in order to properly fit its container, and bringing out one free end through a slot in the side of the box. This method of packing also tends toward an economical use of the material.

Tincture of iodine requires special packing. This material contains considerable alcohol which would evaporate if left unsealed so that the residual solution would soon become so strong in iodine that it might cause burns when applied to the skin. Accordingly, it is put up in small sealed glass ampoules intended to

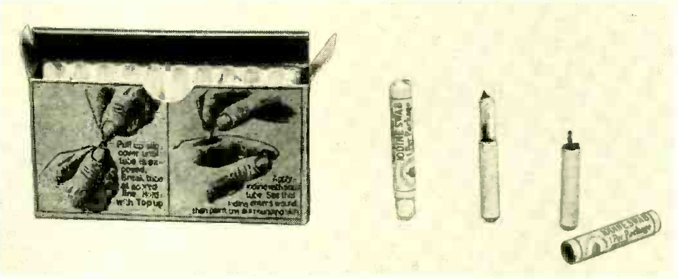


Fig. 3—Ten packages, each containing one iodine swab, fit into a "D" container

be broken and used, and then thrown away. Each ampoule contains on the average only eight drops, and there is thus little danger of burns or local skin irritation from the use of this small amount. To facilitate their use, the ampoules are scored so that the top portion can easily be broken off with the fingers. The bottom portion of the tube containing the tincture also has in it a separate small capillary glass tube which is used as a swab to apply the iodine. Because of this construction, these tincture of iodine ampoules are called "iodine swabs". Aromatic spirits of ammonia are also packed in sealed glass ampoules to prevent evaporation of their contents. When used, the ampoule is broken at a scored line and the contents poured into a glass of water and taken internally.

The quantities of some first aid materials used in the Bell System are amazing. Thus, the gauze and muslin used in the first aid products purchased in the last four years totaled to almost a million square yards. This would cover about a hundred average city blocks.

The provision of first aid supplies and instructions in their use is one factor in reducing the seriousness of accidents when they occur, and minimizing lost working time. Other factors are safety practice instructions, improved supervision, better trained personnel, and safer tools and equipment. Such safety measures have proven very effective. Among the men workers in the outside and inside telephone plant of the Bell System, the time now lost as the result of accidents averages about one day per employee per year, and the accidents per 1000 employees per year has decreased from 60.1 in 1922, to 5.46 in 1932.

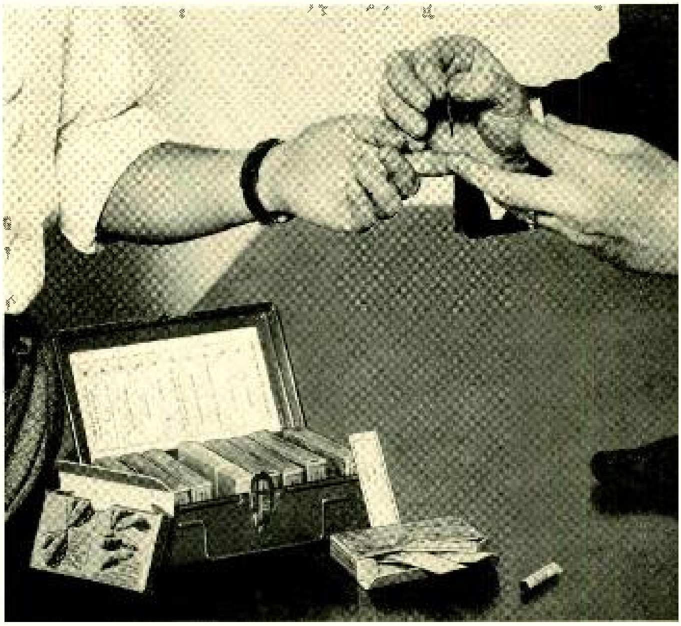
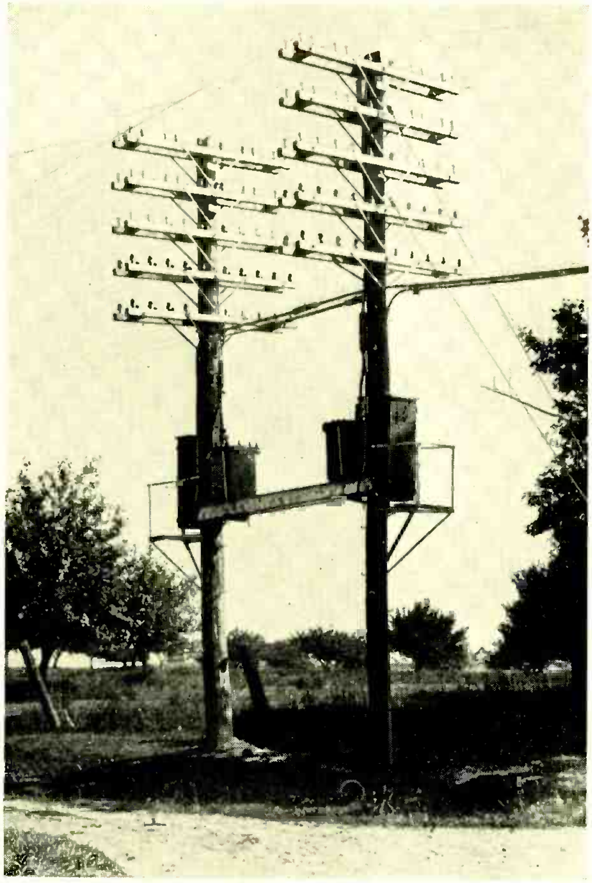


Fig. 4—Using an iodine swab quickly obtained from an "M" type kit



Entrance Cables for Carrier Toll Circuits

By R. P. ASHBAUGH
Outside Plant Development

THE rapid growth in the use of telephone cable—a three fold increase in cable wire miles from 1920 to 1930—has been frequently commented upon. It should not be overlooked, however, that during the same period the mileage of open wire lines has increased 50 per cent. The impression commonly received is perhaps that each section of new toll cable replaces a like length of open wire line, and that as a result the pole lines are disappearing. Although open wire lines are not decreasing, they are being carried to a greater extent along private right-of-ways and along the less travelled roads, and are thus less in evidence. Moreover as they approach a town the overhead wires disappear; their place is taken by a toll entrance cable either aerial or underground that carries the telephone circuits either to the central office or through the town. Such a change from open wires to cable is shown in the photograph at the head of this article. This construction keeps the open wires off city streets and furnishes greater protection to the circuits in the built-up districts.

In the early days, when only voice frequencies were used for toll circuits, these toll entrance cables were essentially small toll cables. Such cables are made up of quads—two pairs of conductors grouped together to provide a phantomed group.* Three sizes of conductors are used for open wire lines—165, 128, and 104 mils in diameter respectively—and to match these three sizes, quads of No. 13, 16, and 19 gauge wire are employed. A cross section of such a typical toll entrance cable is shown in Figure 1. It differs from the standard toll cable chiefly in having a number of non-quadded circuits of small gauge that are used for local service along the route.

Cables of this type are not suitable for carrier circuits because of the greater likelihood of cross-talk at the higher frequencies. As more and more open wire lines were being used for carrier, therefore, it became necessary to design toll entrance cables suitable for carrier service with frequencies not exceeding approximately thirty kilocycles. For such circuits some form of shielding is necessary to obtain the required freedom from cross-talk. The shielding may be obtained by a complete enclosure of the carrier circuit by braided tinsel or an overlapping serving of lead, brass, or copper tape, the material and thickness depending upon the cross-talk limits. With such construction all the circuits in the cable can be used for carrier operation. A less effective method, but one which is satisfactory for a limited number of circuits, is to surround the carrier circuits with others used only for voice frequencies.

The condition requiring relatively few circuits for carrier use was the first requiring solution, and a satisfactory cable was produced by selecting certain quads for carrier use and separating them from each other in the cable layup by other quads to be used for voice frequency circuits only. These cables were so spliced in the field that the carrier quads were kept effectively separated by the voice frequency circuits. The carrier circuits, however, were usually put on the highest grade of open wire lines, which were the ones largest in diameter requiring entrance-cable conductors of a large gauge, such as 13 or 16 gauge, for voice frequency purposes as well as for carrier. This fact, in turn, called for a cable layup wherein, for example, No. 13 gauge quads should be guarded on all sides by quads of smaller gauge, whereas the usual practice in laying up toll cables of different gauges of

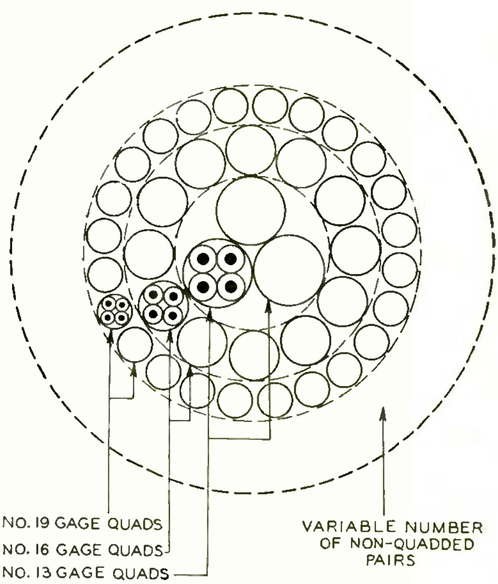


Fig. 1—Cross section of one type of toll entrance cable not designed for carrier circuits

*Record, *March* 1930, *p.* 309.

conductors was to have full layers of one gauge, the larger gauges generally being placed in the center and smaller gauges in the outer layers. It became necessary, therefore, to determine entirely new setups for the amount of insulation to secure the desired capacitances, and to select lengths of twists with special care to avoid large capacitance unbalances when quads of different gauges were placed in the same layer. Figure 2 shows the layup of a representative cable of this type. Here the three No. 13 gauge quads in the layer next to the center and the nine No. 16 gauge quads in the outer layer are suitable for carrier use. In this type of cable a maximum of approximately 25% of the circuits are suitable for carrier. Twelve cables have been standardized for this kind of use, nine of which provide combinations of two or more gauges. To

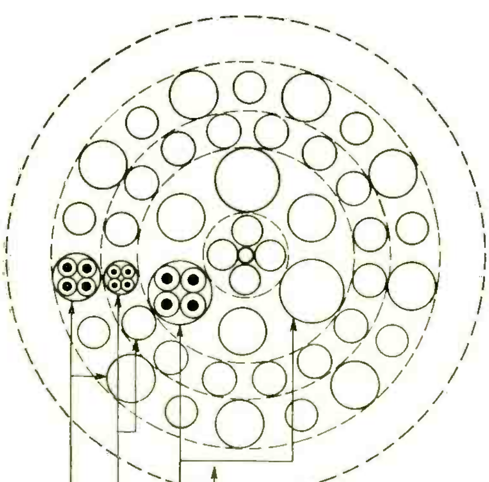


Fig. 2—By letting voice-frequency circuits act as shields for carrier circuits, about one quarter of the quads in a cable may be used for carrier operation

assist further in making these cables suitable for different field conditions, each of these twelve cables may be obtained with various numbers of small gauge exchange circuits.

Shortly after this development, a new and improved design to be used for important open wire lines was standardized. In this design, non-phantomed operation and, in some cases the closer spacing between wires on the cross arms permitted the use of a larger portion of carrier circuits. This required that non-quaded pairs of No. 13 and No. 16 gauge suitable for carrier operation should be included in the entrance cables and in some cases that approximately half of the circuits in a cable should be suitable for carrier operation. Two types of construction were investigated to meet these new conditions. In one, the individual circuits required for carrier use were shielded by an overlapping spiral of metal tape and these units laid up in the cable with the required number of pairs and quads of regular construction needed for the voice frequency circuits. In the other construction carrier circuits were shielded from each other in any one layer by alternating with voice frequency circuits, and the use of a shielding tape between layers permitted carrier circuits to be selected from every layer.

From previous studies it was known that the construction using individually shielded circuits would prove satisfactory with respect to freedom from cross-talk but it was also known that the construction was costly, not only because of the additional materials and labor required in the units themselves, but also because the presence of the metal of any shield increases the capacitance of all circuits near it unless additional space is allotted to them, thus increasing the amount of insulating and sheathing material. An individually shielded unit occupies approximately two to

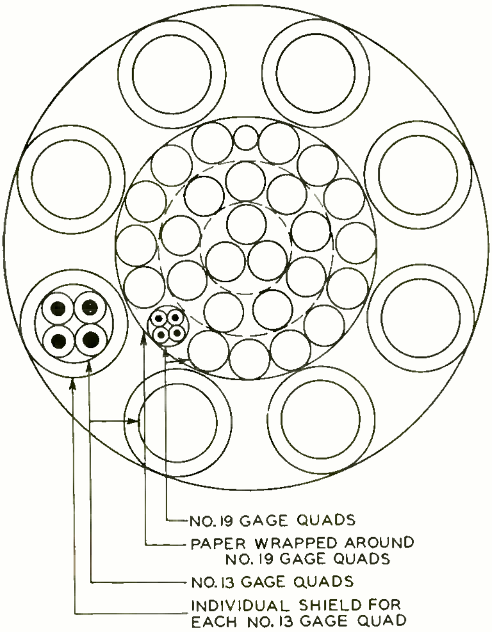


Fig. 3—Another form of toll entrance cable employs eight individually shielded quads for carrier circuits

two and one-half times as much space as an unshielded unit in a regular toll cable and costs approximately twice as much. To meet the urgent need for carrier toll entrance cable, however, a number of cables with such shielded circuits were designed and manufactured for use in the telephone plant. A representative cable of this type is shown in Figure 3.

With the other type of construction mentioned above, metallic shields are placed between the layers of quads and pairs and within the layer carrier circuits are alternated with voice frequency circuits. In this way approximately half the total circuits in the cable can be used for carrier. With shields on either side of a layer and numerous combinations of pairs or quads or both adjacent within a layer, it was found necessary to determine anew the proper amount of insulation for the various types of circuits to keep uniform values of capacitance. These problems were solved for the greater part in conjunction with commercial manufacture. This construction was found to be satisfactory in service and is intermediate in cost between individually shielded circuits and cable with no shielding. Such construction was also found to have a very desirable service flexibility. For example, at that time the changing of some of the more important open wire lines from the phantomed basis to the non-phantomed basis was undertaken. In connection with this work, a type of cable was required for use in many cases where it was

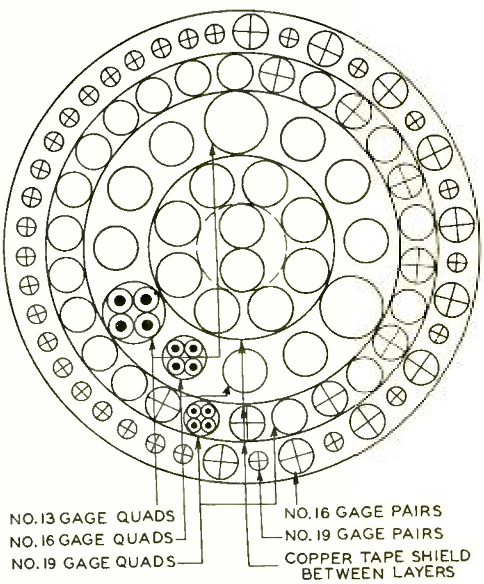


Fig. 4—By employing metallic shielding between layers and alternating carrier with voice-frequency circuits within the layer, a large percentage of the pairs and quads may be made suitable for carrier operation

necessary to bring in both phantomed and non-phantomed lines. With the type of cable discussed above and a suitable arrangement of non-quadded pairs and quads in a layer, the cable could be connected so that carrier on phantomed open wire circuits would be routed through the quads, in which case the non-quadded pairs would serve as shields. The cable could also be connected so that carrier circuits would be routed through the non-phantomed pairs, the quads serving as shields. This type of cable would also prove advantageous if, at a later date, it is desired to rearrange a phantomed line for non-phantomed operation, since the non-quadded pairs which initially served as shields could be used for entrance purposes while the quads could serve as shields after the rearrangement. The cable layups developed under this somewhat fortuitous situation were found to be so desirable that eleven of them have now been standardized. Figure 4 shows a layup of a typical cable of this kind.

The development of these cables has been practically a continuous performance since 1928 and has gone hand in hand with commercial production. Already over 500 miles of toll entrance cables suitable for carrier operation have been placed in the telephone plant and form important links in the communication system.

World Wide Telephone Service

In the short space of seven years, since January 1927 when the radio-telephone circuit between the United States and Great Britain was opened, amazingly rapid progress has been made in linking the countries of the world by telephone.

Today, from any part of the United States, telephone connections can be established with a total of 30,000,000 telephones, or 92 per cent of all the telephones in service in the world. Any user of the Bell System's service can be connected upon request with any one of 1,350,000 telephones in Canada, 96,000 in Mexico and 50,000 in Cuba. and can reach by wire and radio 10,500,000 telephones in Europe, 560,000 in Central and South America, 110,000 in Northern and Southern Africa, 450,000 in Australia, besides those of various island groups throughout the world, including Bermuda, Hawaii, the Phillipine Islands, the Canary Islands, the Balearic Islands, the Bahama Islands and the Dutch East Indies.

Distributing Toll Tickets by Pneumatic Tubes

By R. E. OTTMAN
Equipment Development

WHEN you ask for a long distance connection, the details of the call are recorded by a toll operator on a ticket as shown in Figure 1. On the back of the ticket are stamped the time of the beginning and the length of the conversation in minutes. At the completion of the call the ticket is filed and becomes a record for billing.

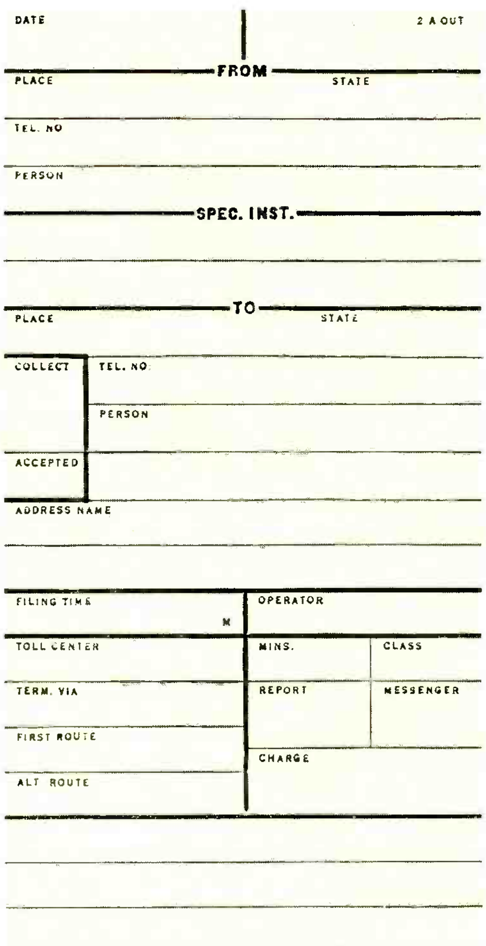
In the larger offices the number of tickets to be handled is very great. In the New York toll office, for example, over 30,000 calls may be completed in one day or about 3,000 during a busy hour. Besides these there are a large number of additional tickets such as those for cancelled calls, report tickets, and call order tickets. Since many of these make two or more trips between various points, there may be upward of 75,000 ticket trips per day. It is essential, therefore, to have a distributing system by which the tickets may be transferred from one point to another with a maximum of convenience to the operator, and with a minimum of time so that there will be no unnecessary delay or confusion in completing the calls. It is essential also that the tickets should not be lost or mutilated because they are the records from which charges are made, and in addition they must be available at all times to make it possible to answer requests for charges.

In many of the toll offices, tickets are carried from place to place by messengers, and in others tickets are passed along the board from one operator to another. As early as thirty years ago, however, some offices had grown to such a size that the volume of tickets to be handled required a more efficient means of transportation. The pneumatic-tube distributing system was developed at that time to meet the needs of the larger offices. In this system as originally developed, the tickets were sent through rectangular brass tubes of 3/8″ x 2 3/4″ inside dimensions from which the air was continuously drawn by means of an exhauster. Differing from usual pneumatic tube systems no cartridge or other mechanical carrier was provided; the tickets were arranged to act as their own carrier and inserted directly into the air stream.

The need for such a system arose from the method of handling calls in use at that time. One group of operators, known as recording operators, took down the details of the call on the ticket, and then told the subscriber to hang up and that he would be called as soon as the connection was completed. If no directory information was needed, the recording operator forwarded the ticket to an outward operator. If directory information was needed, she sent the ticket to a directory desk, where this information was added. The directory operator then forwarded the ticket to the outward operator, who handled the completion of the call. After the call was completed, the ticket was sent to a central filing desk.

Unless a considerable time was to be

consumed in completing each long distance connection, some means of moving tickets quickly from one point to another had to be provided. Carriers such as are used in department store cash systems could not be used because the carriers would take up valuable space on the switchboard key-shelf and require too much time in handling. Also, the empty carriers would have to be returned to the recording board, since the flow of tickets was largely in one direction. The thin rectangular tube, on the other hand, could be located out of the way under the keyshelf of the switchboard. To get the ticket to act as its own carrier, a flap was turned back at one end as shown in Figure 2. The force of the air acting on the flap pulled the ticket through the tube.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MINS.
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TERM. VIA
REPORT
MESSENGER
FIRST ROUTE
CHARGE
ALT ROUTE

Fig. 1—On the front of the toll ticket is recorded all essential details of a call, and on its back is stamped the time of beginning and the elapsed time of the conversation.

Since the operators at the outward board each handled calls to certain destinations it was necessary for the recording operators and directory operators to be able to send tickets to particular positions. As it was impossible to provide a tube from each recording position to each outward position this could be done only by their sending all tickets to a distributing desk from which they were forwarded to the proper positions. At these distributing desks as well as at the filing desks, the incoming tubes were terminated in continuous delivery valves from which the ticket dropped on a tray in front of the operators. At the switchboards the tubes running to the distributing or filing desks were made common to a number of operators. A sending valve was placed between the two operators of each section and a maximum of nine valves was put on one tube. Since a switchboard might have as many as sixty or more positions it was necessary to bring the tubes out of the board between sections as shown in Figure 3. Tubes from the distributing desk to the outward switchboard were individual to one section, and terminated in a hand operated valve from which the operator or supervisor could remove the ticket by operating a lever.

The system as described above, has been in use in all the larger toll offices since its development. It has met the requirements of speed, convenience, and reliability very well. The possibility of tickets becoming lost is very small since there is no place for them to leave the tubes except at the terminals. Furthermore, the forces exerted on the ticket by air currents are not sufficient to tear or mutilate them. Since the tickets travel at a speed of thirty feet per second, practically no

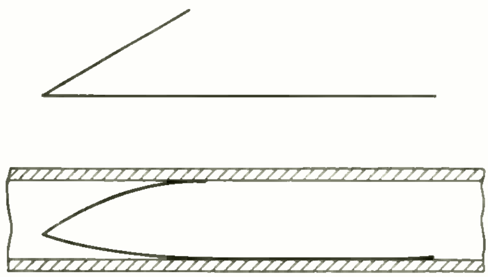

Fig. 2—Tickets in the past have been folded back at the front end to form a flap for the air current to act upon

time is lost in transferring them from one location to another.

Occasionally, however, some trouble has been experienced from tickets becoming stuck in the tubes. This is most likely to happen in humid weather. When one ticket becomes stuck, others following may lodge behind it and form a blockade. This condition led to an investigation to determine what means could be adopted to overcome this trouble. A study was made also to see what could be done to reduce the cost of the system since it was not economical for use in any except the larger toll offices. As a result of these studies changes have been put into effect that have made the system not only more reliable in all weather conditions, but economical enough to find application in many toll offices where the cost of pneumatic tubes previously could not be justified. A few years ago changes were made in the method of handling calls which made possible a simpler tube system.

Figure 4 shows schematically a typical pneumatic tube system as now used. It will be noted that there is no recording board and no directory desk to which tickets are sent. The method of handling calls is now such that the first operator with whom the subscriber comes in contact is a combined line and recording operator, that is she both records the detail of the call on the ticket and proceeds to establish the connection. Directory information, if required, is obtained over a trunk. The "CLR" operator completes the connection at once, if possible, but if this cannot be done in the first few minutes, she dismisses the subscriber and forwards the ticket to an operator handling delayed calls (point to point). At the end of the conversation the tickets are sent by the operator to a filing desk where

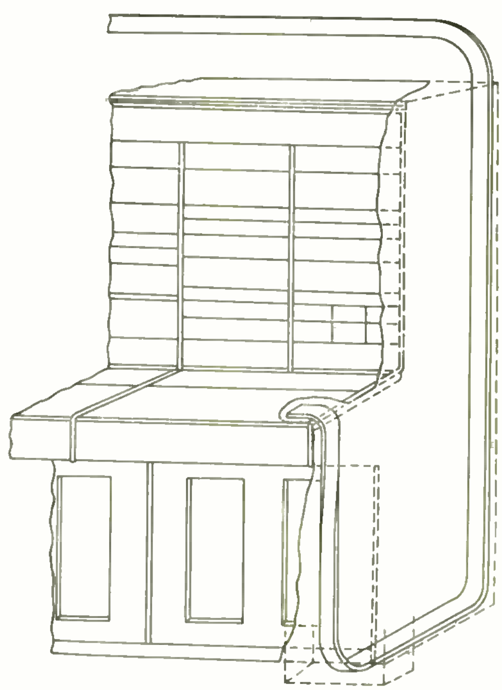

Fig. 3—Tubes were formerly led from switchboard by being carried down to the floor and then up the back of the board between sections

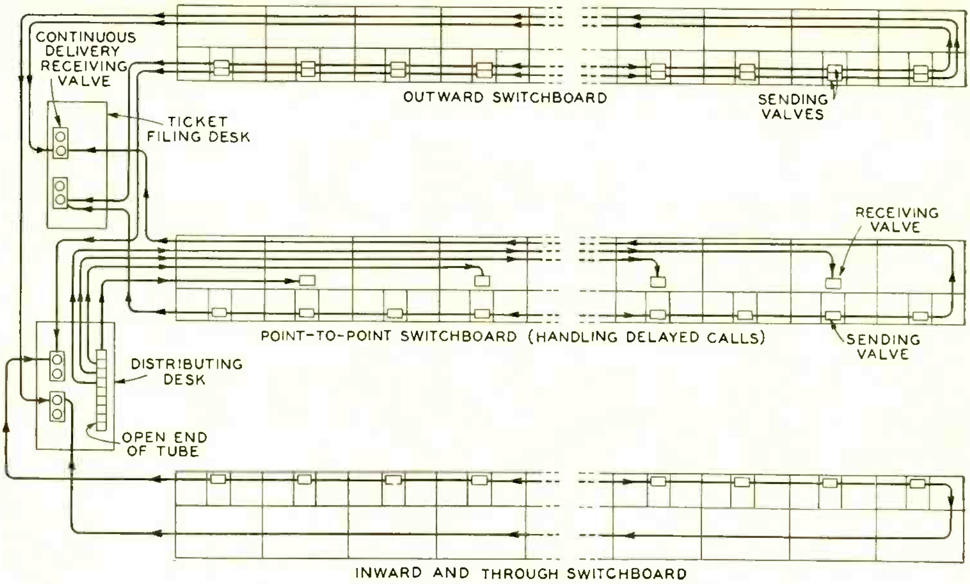

Fig. 4—A typical pneumatic tube distributing system for three lines of switchboard

they are filed according to destination of call. While a large proportion of the tickets thus make only one trip, some of them have to be transferred from one location to another nearly as many times as formerly.

In studying the causes of tickets becoming stuck in the tubes it has been found that it was due usually to an accumulation of moisture in the tube, and that its likelihood was greatly increased by the number of bends and twists. The accumulation of moisture, which is most evident in humid weather, has been overcome to some extent by providing heaters at critical points, which tend to prevent the accumulation of moisture.

The number of bends and twists has been reduced to a great extent by simplifying the tube runs. As already stated, the number of sending valves per tube running from the switchboard to the filing or distributing desk was originally limited to nine. In bringing the tube out between sections as shown in Figure 3, three flat bends, a twist and an edgewise bend were required, and a casing around the tube between the keyshelf and the floor had to be provided to protect the tubes from injury from operators' chairs. It was found, however, that as many as eighteen valves could be operated on one tube, which makes it possible to serve most of the lines with but two tubes.

With only two tubes per switchboard, there is no need of bringing the tubes out between sections. The two tubes can start near the middle of the board and be brought out at the ends as shown in Figure 5. With this arrangement not more than two flat bends and an edge bend are required, thus saving at least a flat bend and a twist for each tube as well as the tube casing which interfered with the adjacent operators and detracted from the appearance of the switchboard. In addition the bends have been made of larger radius so that the tickets are less likely to stick, even in moist weather.

Another change that has appreciably increased the reliability of the system is a new method of folding the ticket. In the past, an inch and a half of the front end of the ticket has been folded back as shown in Fig. 2. When the ticket is inserted in the tube, it assumes the position shown, and is carried along with the air current. It will be noticed, however, that the ticket has a tendency to drag on both top and bottom surfaces of the tube. Although this dragging slows up the speed of the ticket, the chief objection to it is that it makes the tickets more likely to stick to the tube when moisture is present.

Studies have shown that a small fold at the rear of the ticket acts as a deflector, lifting the long section of the ticket clear of the sides so that its speed is increased and the likelihood of sticking due to moisture greatly decreased. This fold and the position the ticket assumes in the tube is shown in Fig. 6. Comparative tests on the two types of folds under conditions of relative humidity as high as 90% have shown that this rear fold reduces the

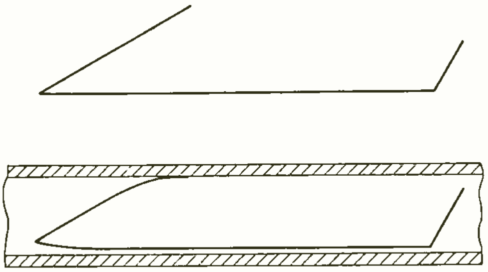

Fig. 6—At the present time a ticket is given a short fold at the rear as well, and the action of the air tends to keep the ticket away from the surface of the tube and thus to reduce the friction

number of tickets delayed by 50%, and that the speed of the ticket with the rear fold is 10% greater, under average conditions than that of a ticket with a single fold.

These changes, by contributing to the reliability of the system, have had a tendency to reduce the maintenance charges. Another change, which has resulted in very material savings, is the adoption of a less expensive paper. Formerly a comparatively high grade rag ledger paper was used for the tickets. With the simplification of the tube runs and the use of the rear fold, a relatively low grade of paper known as sulphite ledger may be used with equally reliable results.

These various modifications have decreased the cost of the system and at the same time appreciably improved its dependability. Combined with a decrease in maintenance costs, they have quite naturally widened the scope of the economical employment of pneumatic tube distributing systems.

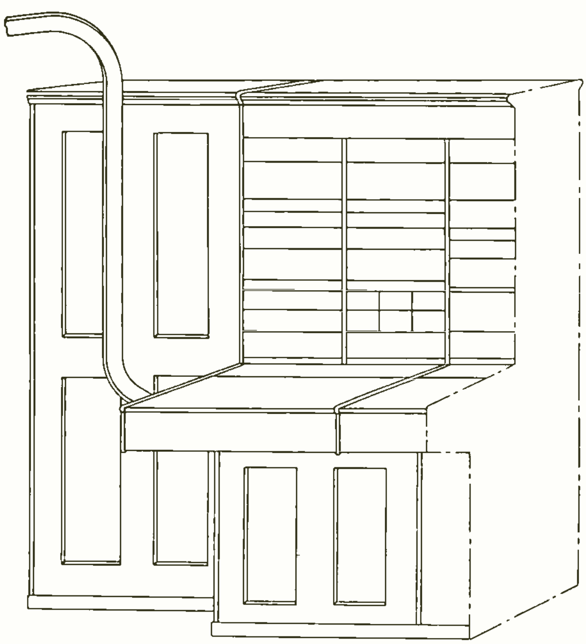

Fig. 5—With the new system only two tubes are required per line of switchboard, and they are brought out at the ends

Moving the Toll Ticket

By J. R. STONE
Equipment Development

IN all the larger toll offices, and in many of the smaller ones, pneumatic tube systems are employed for carrying toll tickets from the operators to the filing desk, or to a distributing desk for forwarding to other operators. Exhauster sets are used to draw air through the tubes at the proper velocity to carry the tickets between the sending and receiving points. The exhauster must be designed to create a sufficient vacuum at one end of the tube so that the air will be drawn through at the required velocity, and to have sufficient capacity to care for the number of tubes necessary for the office. The amount of vacuum required depends on the length of the longest tube in the office, and the capacity, on the number of tubes. Since the size and arrangements of the toll offices vary considerably, both of these factors have a wide range of values, and a number of standard exhausters must be provided to take care of all conditions.

Pneumatic ticket distributing systems have been in use for well over a quarter of a century, and at the time they were first installed the only reliable and suitable exhausters available were of the positive pressure type. A

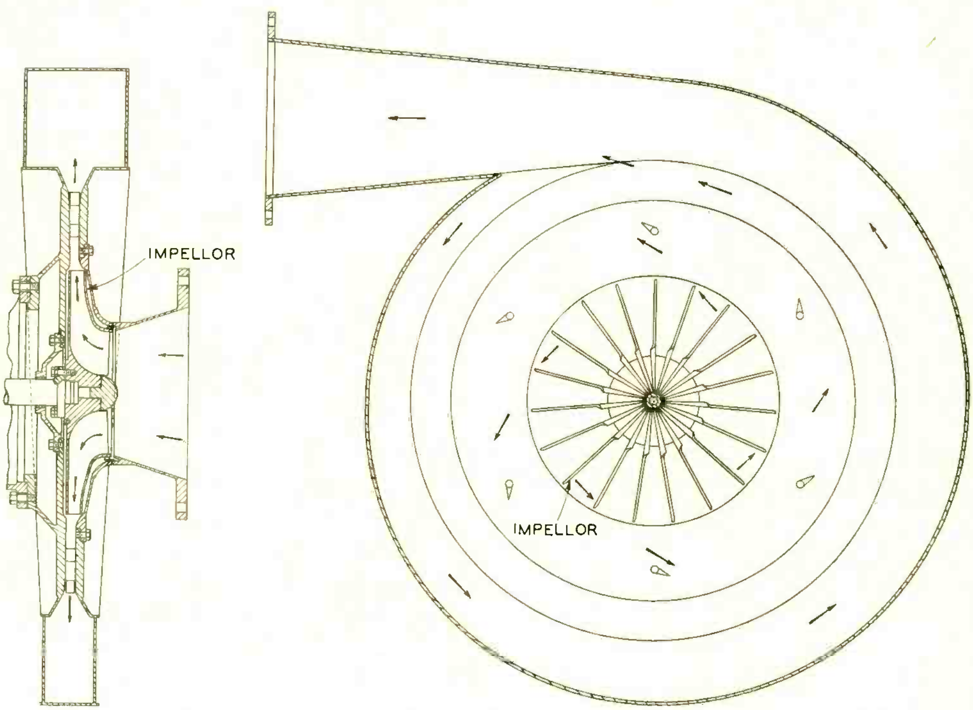

Fig. 1—Cross-section of typical centrifugal exhauster

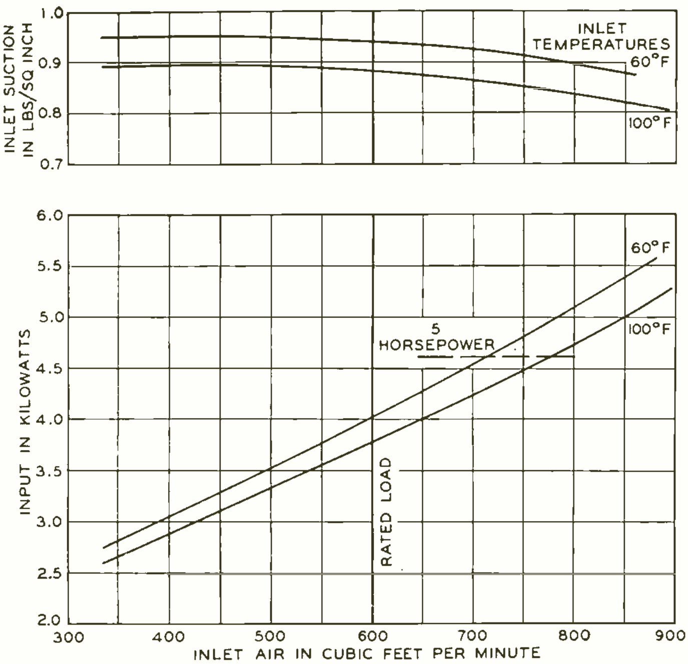

Fig. 2—Typical characteristics of a centrifugal type exhauster

definite amount of air is taken in at the suction pressure at each revolution and delivered at the outlet pressure of the pump. The amount of air the pump can handle is constant, therefore, for any one speed of operation. Since the number of tubes in use varies from time to time, it is necessary to drive the pumps with adjustable speed motors so that they can be speeded up or slowed down as the number of tubes is increased or decreased. These exhausters are essentially slow speed machines and belt or chain drives are used to avoid the high costs of low speed motors.

Although these positive-pressure type exhausters are entirely satisfactory from the standpoint of drawing air through the tubes, they are large and heavy, and are inclined to be noisy in operation. It is necessary to install them on heavy foundations in the basement and to run the suction pipes to the upper floor where the ticket tubes are usually located. The foundations have to be isolated from the building floor by cushions of sand or cork to avoid transmitting the low-frequency vibrations to the building structure, and flexible sections are employed in connecting the machines to the piping systems for the same reason.

Because of the pulsating nature of the discharge and of the resulting noise, discharge ducts of large

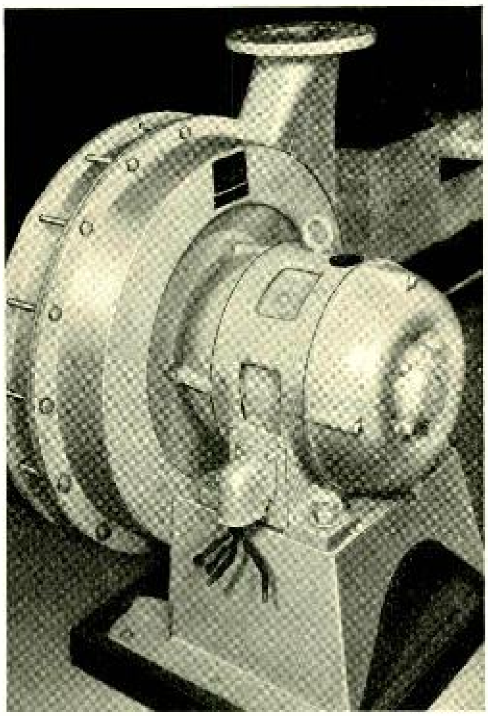

Fig. 3—A centrifugal type exhauster of 200 cubic feet capacity at one pound pressure

cross-section are required to carry the air to the outside of the building. The large volume of these discharge ducts serves to reduce the pulsations of the discharge, and to make it quieter.

During recent years much progress has been made in perfecting a centrifugal exhauster, and now highly efficient and reliable types may be obtained. Their construction is shown in the cross-section sketch in Figure 1. Such a set consists of a motor-driven impellor divided into sections by radial vanes and housed in an outer casing. The suction connection is around the central shaft, and when the impellor is running, centrifugal action throws the air out around the circumference at high velocity. The outer casing forms a tapering duct of steadily increasing size around the periphery of the impellor, and carries away the discharged air.

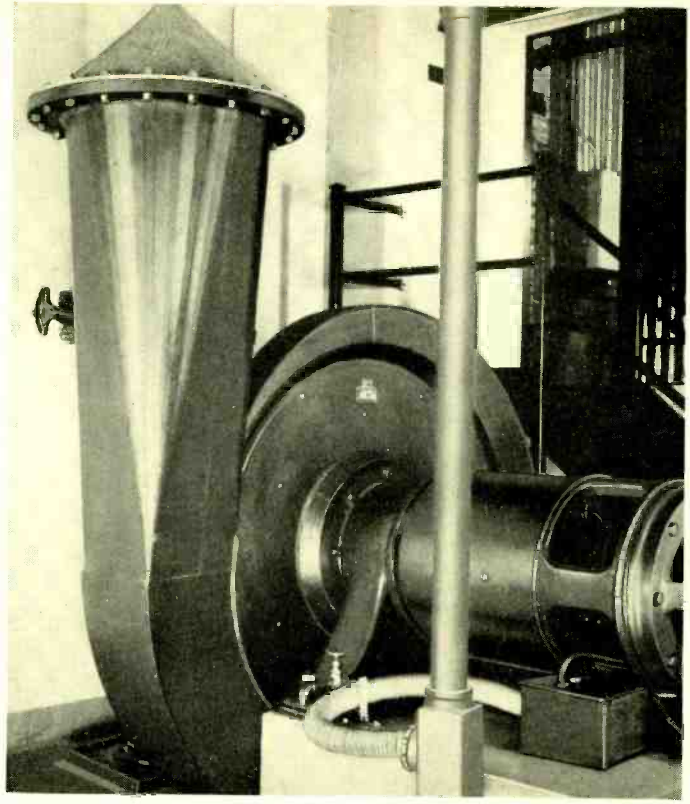

Fig. 4—The greater quietness of the centrifugal blowers permits discharge directly into the room

These centrifugal exhausters operate at an essentially constant suction over a wide range of volumes. The characteristics of a typical machine are shown by the graphs of Figure 2. As more tubes are connected to the system, more air will be handled by the exhauster and the power required to drive it will increase as a result, but the suction remains nearly constant. They have the advantage of being inherently high speed machines, and since speed adjustment is not necessary, a constant speed drive motor may be directly coupled to them. Compared to the positive pressure machines, their size and weight per unit of output are small, and because of the steady flow of air passing through them, their discharge is in general less disturbing and can usually be permitted to flow directly into the room.

These many advantages of the centrifugal type exhauster have led to their use in all recent installations. The earlier types, and the larger sizes of the present type, have sleeve bearings and a high-pressure lubricating system. Oil is pumped only when the exhauster is rotating in the normal direction. Because of this, when two exhausters are connected to the same system to provide a spare unit, some means must be taken to prevent air from flowing through the exhauster not in use and driving it in the reverse direction. To avoid such a reversal and the possible damaging of the bearings, a self closing gate is installed in the intake line. With flow of air in the normal direction this valve remains open, but on a reversal of flow, it immediately shuts and thus prevents the reverse operation of the exhauster.

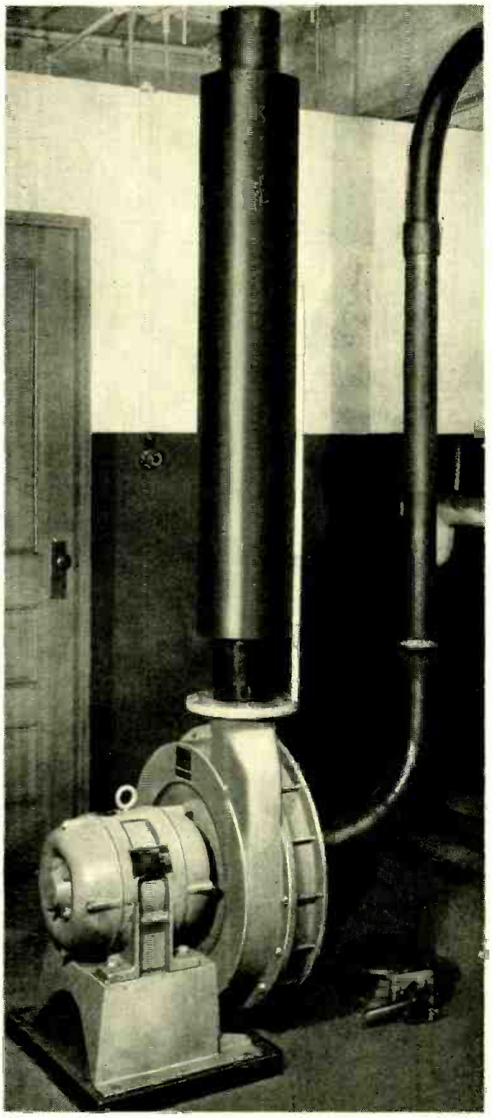

Fig. 5—Discharge silencers are employed where very quiet operation must be insured

The more recent machines, except the largest sizes, are equipped with ball bearings, which simplifies their operation and makes it unnecessary to provide automatic gates, since the lubrication of the bearings is effective regardless of the direction of rotation. With these machines, hand operated valves, of the type shown lying on the floor in Figure 5, are provided however, to isolate the idle machine when two machines are used. A typical unit of the ball bearing type is shown in Figure 3. A set with sleeve bearings and forced lubrication is shown in Figure 4.

Although the discharge of the centrifugal exhauster is much quieter than that of the positive pressure type machine, it is not sufficiently quiet where no appreciable noise is tolerable. To meet such conditions a silencer has been developed and is shown on a small set in Figure 5.

A number of machines of different capacities is provided for each of three pressures. The pressure rating is roughly the pressure difference between the intake and outlet, and the three pressures employed are 1, 1¼, and 1½ pounds per square inch. The one pound units range in capacity from 100 to 3000 cubic feet per minute; the 1¼ pound machines, from 100 to 3500; and the 1½ pound machines, from 150 to 6200. Larger machines are occasionally required and the one shown in Figure 4 has a capacity of 9000 cubic feet at 1½ pounds.

The operation of centrifugal type exhausters has shown them to be efficient and dependable for use with pneumatic ticket distributing systems in telephone toll offices, and they are now used as standard equipment for all new installations.

Long Distance Telegraph Circuits

By T. A. MARSHALL
Toll Development

WIRE telegraphy, which was the first form of electrical communication, still maintains its important position, and is even extending its field of usefulness. Although the telephone has its advantages for many purposes, it requires greater circuit capacity than the telegraph, and does not leave a written record, which may be easily obtained telegraphically by use of teletype machines. The economy in circuit capacity arises from the simple nature of the telegraph signals compared to the more complex speech waves of the telephone. For telephony the quality of the human voice must be transmitted instead of the dots and dashes of the telegraph code, with the result that twelve telegraph messages require no wider band of frequencies than a single voice message.

The original telegraph operated on direct current, and the opening and closing of the circuit at the proper intervals gave the code signals. Because of the simplicity of this type of operation, and of the desirability of having all subscriber loops send and receive the same kind of signal, the simple on and off, or neutral, signal is employed for all subscriber loops except in a few cases where the polarized signal, alternate positive and negative currents, is used instead.

Although the signals to and from the subscriber's premises are all alike for the most part, the actual signals passed over the transmission lines may differ considerably. Carrier transmission, at both voice and high frequency, gives, of course, distinctly different and unrecognizable signals on the line, but other types of transmission, such as grounded duplex and one-way and two-path polar may re-

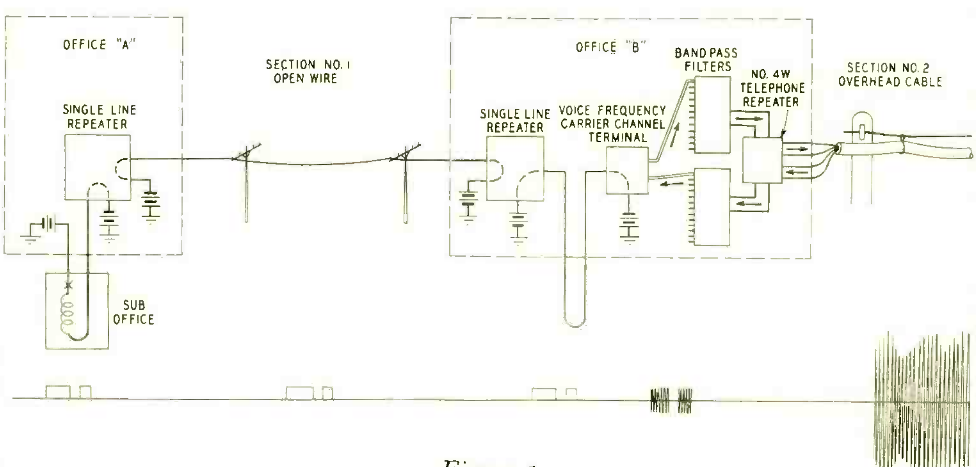

Figure 1

sult in transmitted signals which also differ from those sent by the subscriber. What particular system of transmission is used depends on the length of the circuit, whether it is open wire or cable, on the number of telegraph circuits required over that particular route, and on the plant facilities available. A very long circuit may, and usually does, comprise a number of line sections and the type of transmission may be different in each section. A complicated circuit network may comprise as many as six or seven line sections in tandem with a much larger number connected to the main circuit as radiating branches at suitable repeater points.

Regardless of the type of transmission employed over the line, each section terminates in a suitable repeater, from which sending and receiving legs run to the telegraph test board. All subscriber loops also run to the test boards so that it is a comparatively simple matter to build up the circuit desired by patching between jacks or by cross connecting between terminals depending upon the degree of permanence required. Here subscriber loops may be taken out or added as desired, and the circuit extended from office to office by the most suitable facilities as the routing demands.

Facilities at the subscriber's premises may be either manual telegraph instruments or teletypewriters, and for both types of facilities full duplex, half duplex, or one way service may be provided. With full duplex service, the subscriber is provided with two sets of instruments and may send on one and receive on the other at the same time. This type of service permits maximum use of the facilities, but it is not in very great demand. With half duplex service, the subscriber may also both send and receive, but not at the same time. This is the most widely used service. With one way operation the subscriber either sends or receives but not both. One way service is extensively employed by news distributors and others who wish to send information from one point to a large number of receiving stations.

How these various systems and facilities may be assembled into a long circuit is shown in the accompanying illustrations. These represent a succession of eight offices connected by various types of lines over which several different systems of telegraphy are operated. The form of signal

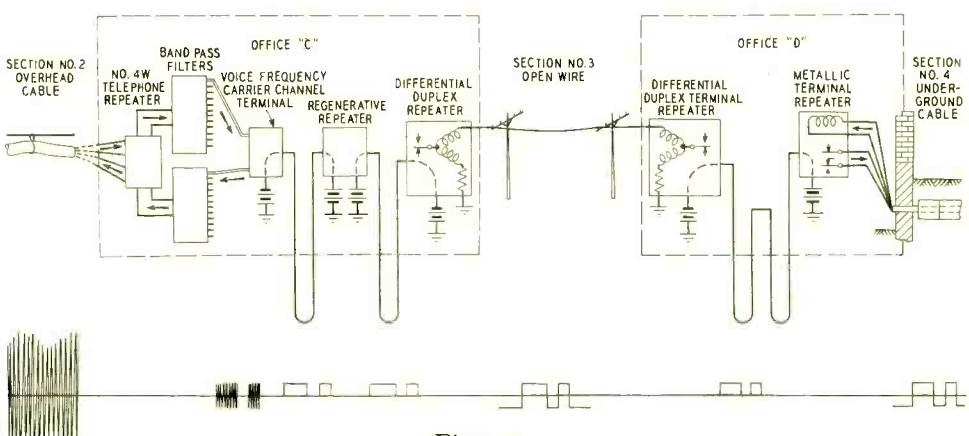

Figure 2

transmitted over the sections is indicated on the horizontal line beneath the illustrations. The subscriber loops may be connected either to teletypewriters or to manual telegraph instruments, although only one form of instrument may be used on the same circuit.

A single wire grounded system, which requires only the simplest form of terminal equipment, is employed over section 1. This type of service is usually employed to reach a subscriber too far away to be served by an ordinary subscriber loop.

At office B this simple grounded system is connected by suitable equipment to a voice-frequency carrier system for transmission over the overhead cable route of section 2. Two pairs of wires are required, but over them 24 one-way channels, 12 in either direction, are provided within the range of voice frequencies. Only two one-way channels are indicated. An additional subscriber loop is shown connected into the circuit at this point. A voice frequency carrier system lends itself to long haul circuits where it is not necessary to drop off loops at intermediate points. Since the signals are at voice frequencies, regular telephone repeaters along the line are employed to provide the necessary amplification.

At office C a transformation from carrier to differential duplex is made. This system operates in both directions, sending polarized signals over a single open-wire line. Two additional loops are added at this office, and a regenerative repeater* is employed to restore the signals, which may have suffered somewhat from their long journey, to their original form. The differential duplex system is also suitable for long hauls, and is the only one that can provide full duplex transmission over one wire.

Section 4 is underground cable to which is applied a four wire metallic system. Direct current transmission in cable must be on a metallic rather than a grounded basis to prevent interference with telephone circuits in the same cable. While also suitable for long distances, the metallic system has the additional advantage of permitting subscriber loops to be dropped off at repeater points along the way.

At office E a transition is made to

*Record, *August*, 1930, *p.* 570.

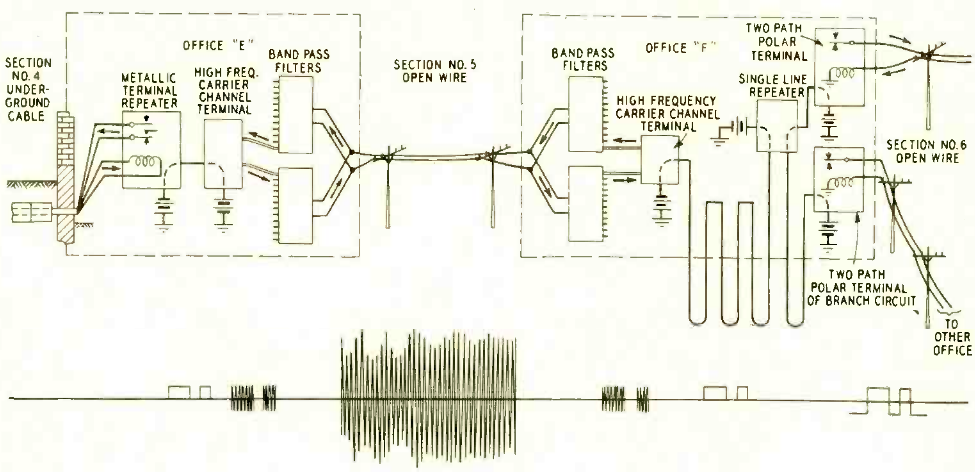

Figure 3

a high-frequency carrier system over open wire lines. Only one pair of wires is required for ten channels in each direction. Such a system lends itself well to the provision of additional communication channels without increasing the wire plant. Like the three preceding systems it also is suitable for long hauls.

Section 6 is also open wire but at office F the transmission system has been changed from carrier to two path polar. This system is essentially two one-way polar systems employing one wire for transmission in each direction. A branch line, also operating on a two-path polar basis, is shown leaving this office and running to an office to one side of the main route.

The two-path polar circuit of section 6 is connected to a one-way polar at office G, where a subscriber loop is dropped off also. The one-way polar circuit extends on open wire to office H from which runs a subscriber loop used for receiving only. This is a simple system, requiring little equipment, and giving very satisfactory transmission for the service required.

The typical system shown in the illustrations gives communication between all the subscriber loops associated with it, and is such as might be used by some newspaper service. Loops may be added at any of the offices as desired, and in some of the sections at any of the repeater stations. The circuit set-up generally changes throughout the day, some stations being connected permanently and others only for short periods.

For switched teletypewriter service, corresponding to ordinary telephone service, circuits are similarly established but on a more permanent basis between switching points, and there will be no subscriber loops at intermediate points. The telegraph facilities available in the Bell System plant lend themselves readily to almost any kind of service desired, and are adaptable to the layout of extensive networks.

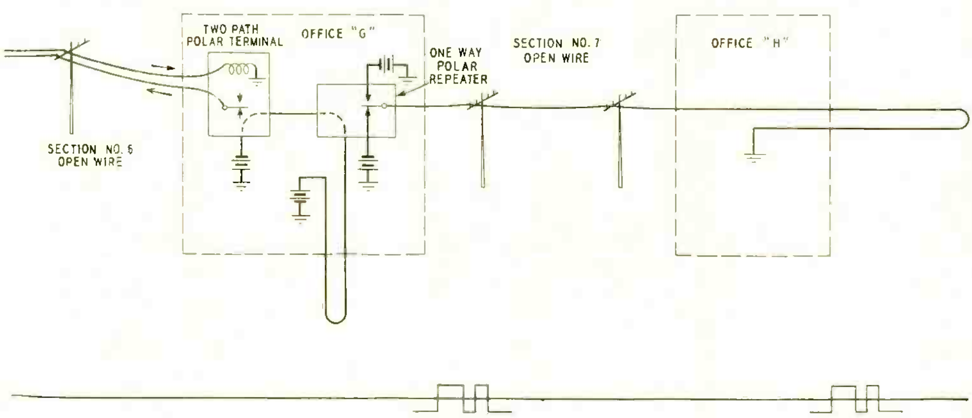

Figure 4

Contributors to This Issue

R. P. Ashbaugh graduated in Electrical Engineering from Ohio University in 1910 and joined the Engineering Department of the Western Electric Company, now Bell Telephone Laboratories, in 1911. After a year spent as a student and a year on loading coil development, he entered the lead covered cable development group and has been in that work continuously since. In 1922 he went to Japan to supervise the placing and splicing of the first toll cable installed in that country and also supervised the engineers of the Sumitomo Cable Works in the design of the first toll cables manufactured in Japan. He returned to the United States in 1924 and has since been located at the Hawthorne Plant of the Western Electric Company where he is now head of the Laboratories' Outside Plant Development Group resident there.

J. R. Stone received an E.E. degree from Cornell University in 1923 and immediately joined the Installation Department of the Western Electric Company, in New York City. The following year he transferred to the power development group of the Laboratories, where he has since been engaged in the development of power machines. He has been particularly concerned with the design of charging machines, ringing machines and centrifugal exhaustors for telephone power plants, and with rotary converters, dynamotors, and motor-generator sets for radio transmitters and receivers.

R. A. Chegwidden joined the Laboratories in 1919 and entered the three-year student assistant course. At the completion of this work he continued his studies at the Brooklyn Polytechnic Institute. Most of his time at the Laboratories has been spent with the Magnetics Research group. He is at present working on magnetic materials with the Apparatus Development Department.

W. H. S. Youry received the degree of Electro-Metallurgy from Lehigh in 1920. After a year with the Westinghouse Lamp Company, he joined the Technical Staff of these Laboratories where he was associated with the Engineering Inspection

R. P. Ashbaugh

J. R. Stone

R. A. Chegwidden

W. H. S. Youry

T. A. Marshall

R. E. Ottman

Department. About six years ago he transferred to the Outside Plant Department with which he is still affiliated. He now has charge of the Miscellaneous Group.

T. A. Marshall received a B.S. degree in Electrical Engineering from the University of Kansas in 1922, and immediately joined the Technical Staff of Bell Telephone Laboratories. After a year spent in the preparation of specifications in the Apparatus Development Department, he transferred to the Toll Development Group. Here he was engaged in the design of test-board and switchboard circuits. More recently he has been occupied with the development of telegraph test-board facilities for the maintenance of telegraph and teletypewriter service.

After graduating with the degree of B.S. in Electrical Engineering from the University of Pennsylvania in 1910, R. E. Ottman remained for a year at the University as an instructor. He then joined the American Telephone and Telegraph Company and for two years carried on maintenance work in the Philadelphia toll office. The following two years were spent with the engineering department of the Cutler-Hammer Manufacturing Company, and in 1915 he joined the Technical Staff of Bell Telephone Laboratories, then the Engineering Department of the Western Electric Company. Here for about five years he was engaged in development work on cords and protection apparatus. Since that time he has been engaged in the development of various types of toll testing and toll switchboard equipment.

Early Telephone Bells

The Historical Museum has recently acquired two bells that were used in 1882 in the first harmonic ringing system for party line telephone service. These bells, shown in the accompanying photograph, were designed by Jacob R. Currier, an undertaker in Lowell, Massachusetts, and were used to a considerable extent by the New England Telephone and Telegraph Company in the Boston and Lowell districts in the early 80's. They were manufactured by Charles Williams, Jr., of Boston, who made the first telephone apparatus for the Bell System.