BELL LABORATORIES RECORD

DIALING FOR RADIO CHANNELS
J. B. BISHOP

A VACUUM TUBE FOR HIGH FREQUENCIES
J. O. McNALLY

TELEGRAPH SIGNALS
J. H. BELL

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BELL LABORATORIES RECORD

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BELL LABORATORIES RECORD

New telephone which is being installed on a trial basis

JULY, 1936

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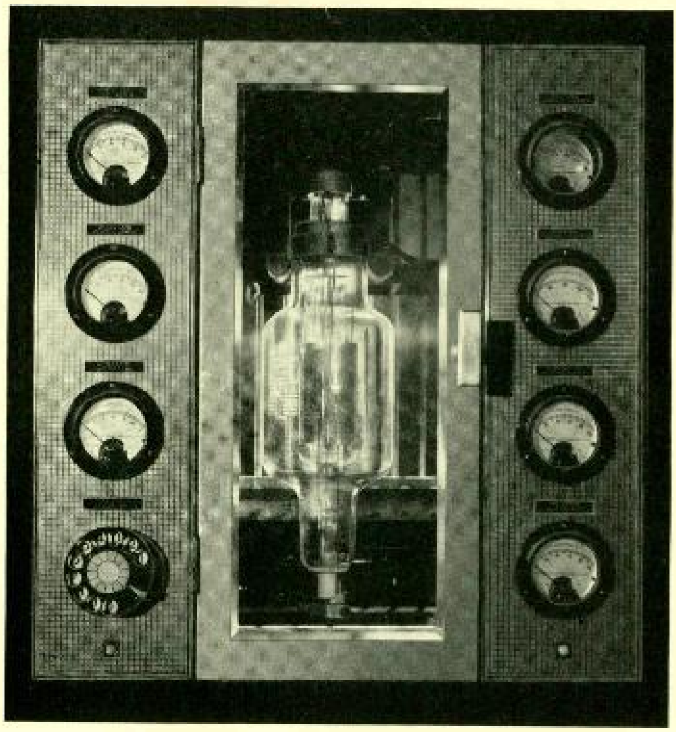


Multi-Frequency Radio Transmitter

By J. B. BISHOP
Radio Development

COMMUNICATION systems in late years have played an increasingly vital role in the field of transportation, and with the public demanding greater speed, greater safety, comfort, and even luxury, a flexible and highly dependable communication service becomes of prime importance. The wire services so valuable to railroads and carriers operating on land are by their very nature incapable of adaptation to communication with mobile units employed in aviation and marine transportation. Radio, on the other hand, while fulfilling the requirements of contact in the air or at sea, has lacked much of the dependability of land wire services. This lack of dependability is largely due to atmospheric disturbances, "skip distance" effects, and the like. Fortunately, however, these qualities affecting radio transmission, while present to some degree on nearly all frequencies, do not affect all frequencies alike. In particular the distance of the "skip" and the amount of interfering atmospheric noise vary not only with time but also with frequency. If a radio circuit were restricted to the use of a single frequency, therefore, there would be considerable periods of time when the channel would not be commercially usable because of noise or because the "skip" distance was not of the right value to allow the signal to be received at the desired point.

If the radio service provided is to approach its full capabilities the engineer must recognize the vagaries of his transmission medium and allow for them. He may even take advantage of the skip distance phenomenon to have his signal carried over a maximum distance with a minimum of power. In general, he secures control of transmission by having several frequencies available for use, so that when one channel becomes unsatisfactory another may be employed. Since some frequencies are freer from disturbances at one time and others at another, the choice of frequency is mainly a matter of time of day or season of year. While the optional use of several frequencies is satisfactory in principle, certain practical difficulties arise in its application. These are due chiefly to the time required to shift the transmitter and receiver from one frequency to another. So far as the receiver is concerned, the changes are ordinarily simple, but in the transmitter, tuning coils and condensers must be changed in several radio stages, and the entire transmitter retuned with each change in frequency. This has been avoided in some instances by employing several transmitters, each tuned to a different frequency and ready for operation at any time. While this latter method of operation is a solution of the difficulty, it is a rather expensive one.

To provide means for transmitting over any of a number of frequencies without the delays consequent to inserting new coils and retuning, or the expense of several transmitters, the Laboratories has developed a transmitter with which any of ten frequencies may be selected merely by dialing one digit on an ordinary telephone dial. The transmitter covers

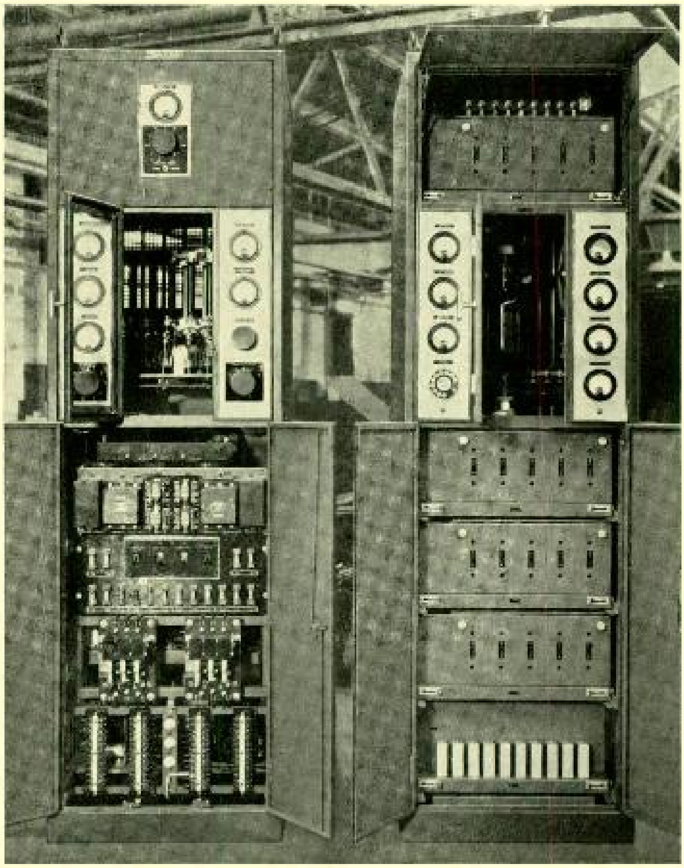


Fig. 1—A unit type construction is employed in the 14-type transmitter (right): the first four radio stages, each with its ten available tuning units, are mounted on a removable chassis. The power-supply unit is shown at the left

the frequency range from 2 to 18.1 megacycles, and may be used for telephone or for continuous-wave or tone-telegraph transmission. Its output of 400 watts at frequencies between two and twelve megacycles, and of 300 watts between 12 and 18 megacycles is capable of substantially complete modulation for both telephone and tone-telegraph transmission.

The same set of vacuum tubes is used for all frequencies, but ten crystals and ten sets of tuning units are provided, and one of each is switched into the circuit according to the frequency dialed. The switching mechanism consists essentially of ten rods running up the back of the transmitter cabinet which are operated through selective clutches by a large solenoid. Each rod when moved up by the solenoid operates a number of switches to connect into the circuit the correct crystal and tuning units for a particular frequency, and to apply the proper power supplies.

A simplified schematic of the radio circuit showing the location of these various switches, is given in Figure 2. There is first a crystal oscillator with provision for switching in a separate crystal and tuning unit for each frequency. Then follow two buffer amplifier stages which may be used either as amplifiers or frequency doublers depending on the frequency used. Each has a tuning unit that is switched into the circuit as required. After these come the modulating amplifier — which has two preceding audio-frequency stages not shown in the diagram—and then the power amplifier—both with their switched-in tuning units. Eleven output terminals are provided. Ten of them are arranged for connection to individual half-wave or balanced transmission-line antennas, while the eleventh, which is common to all the channels, is for connection through a tuning unit to a single vertical antenna. Switches operated by the rods make connection to the proper antenna.

The transmitter is housed in a cabinet seven feet high, two and a half feet wide, and a little over two feet deep. A cabinet of similar size and appearance houses the audio frequency amplifiers and the power supplies for plates, grids, and filaments. These two cabinets are shown ready for operation in the photograph at the end of this article, which was taken at the ground station of the Eastern

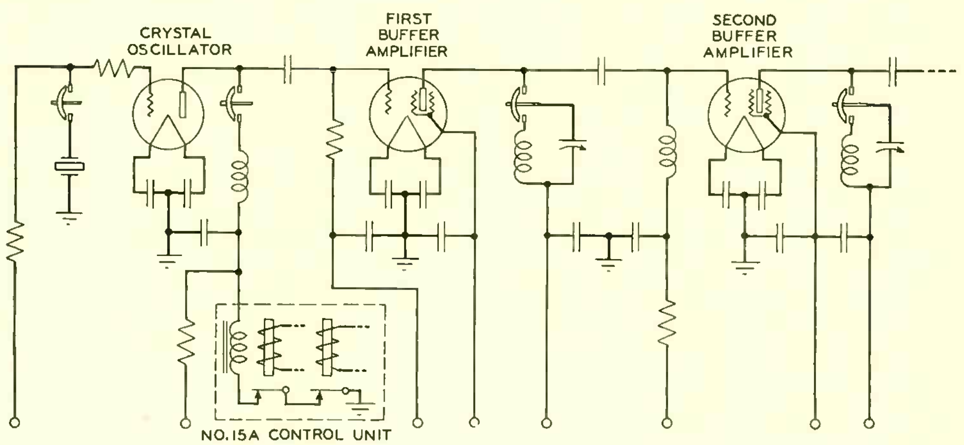
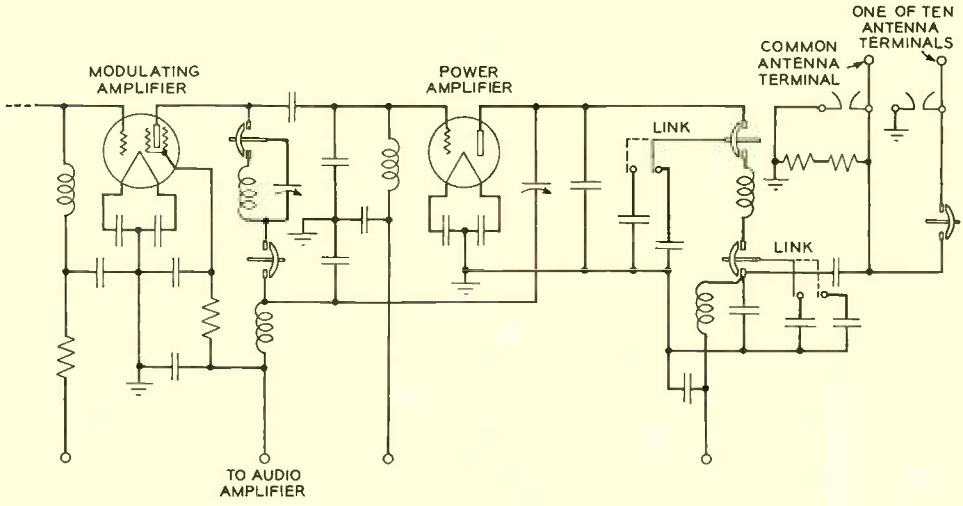


Fig. 2—Simplified schematic of the radio circuit showing switches by which suitable

Airlines at the Newark Airport. The interior arrangement is partially shown in Figure 1. The lower section of the transmitter cabinet contains the first four radio stages, each arranged on a metal chassis that may be slid out for inspection or maintenance by releasing latches on the front edge. Connections to the apparatus are made through wiping contacts in the base of the unit. From bottom to top these chassis carry the oscillator stage, the two buffer amplifiers, and the modulating amplifier. Each carries the ten tuning units for the ten possible frequencies, and the vacuum tube pertaining to the stage. The power amplifier is in the large central section with the glass front. This arrangement, with stages of successively increasing power from bottom to top, provides natural ventilation, which is assisted by a fan in the side of the power amplifier section. The ten sets of tuning coils for the amplifier, and the switches for selecting the correct one, are in the top section.

The rectifier section is also arranged so that apparatus with the least heat dissipation is in the lowest part of the cabinet. This unit, which is supplied by a three-phase 220-volt circuit, houses all power transformers, high and low voltage grid-bias rectifiers and control relays for energizing the various circuits in proper sequence as well as all audio amplifier circuits. The vacuum tubes and resistors are in the center compartment with the glass front, where the tubes may be seen without opening the doors.

Control of the carrier may be either by a "press-to-talk" switch on the handset or desk stand used for talking, or by voice operated relays which operate at the arrival of the first syllable or tone at the speech-input circuit. With this latter method of operation, a type 15 control unit is installed in the top section of the rectifier cabinet. This unit provides for complete control of the carrier by incoming voice or tone signals. Timing relays are incorporated which prevent interruptions between syllables. During idle periods complete carrier suppression is effected by this control unit, which disables the crystal oscillator and thus permits the use of an associated radio receiver.



tuning units are connected into the circuit depending on the frequency dialed

Automatic shut-down of the transmitter is accomplished by two time-delay relays, which remove plate and filament voltages in sequence after a predetermined lapse of time dating from the last word of speech transmitted or the end of a keying pulse. The particular time intervals required for these sequence operations are usually fixed at the time of installation in accordance with the expected schedule of operation, and may be adjusted to any period from one to fifteen minutes. Either or both of these automatic shut-down features may be utilized; that is, the carrier alone may be suppressed during idle periods by disabling the oscillator, or the whole transmitter may be made inoperative by disconnecting the filament and plate supplies.

The connection of the transmitter for the type or types of transmission is usually made at the time of installation. Both the frequency and the type of transmission are then selected by simply dialing a single digit—an operation that requires less than 1½ seconds. When the set is to be operated locally, the dial on the front of the transmitter is employed, but for remote control a second dial may be installed at any point within a radius of several miles. When a radio channel is dialed, the switching mechanism at the rear of the cabinet is first restored to normal position, and then the new radio channel is selected, and all necessary connections made.

The tuning units are all of the plug-in type so that the frequencies available may be changed at any time. Such a change requires but a few minutes. It is necessary only to insert the new plug-in units and to tune each stage independently by a simple screwdriver adjustment. Still another advantage of this arrangement is that when less than the full complement of ten frequencies is required, the user need obtain only the units for the channels that he intends to use. Then at any time he may increase the number to meet his growing needs. This arrangement avoids a high initial outlay for services not immediately required, without limiting the ultimate usefulness of the transmitter.

Reforming Telegraph Signals

By J. H. BELL
Telegraph Engineer

TELEGRAPH signals consist of current impulses of different durations, arranged in the various letter combinations of the telegraph code. Each such signal as it leaves the transmitter is made up of pulses essentially rectangular in shape, and consists of an infinite number of harmonic components.* In passing over a telegraph circuit these harmonics are not all attenuated to the same extent. The attenuation is greater for the higher frequencies. As a result of this unequal attenuation, the signal as received differs in form from that sent out. The beginnings and ends of the pulses—which are most dependent on the presence of the high-frequency components — are rounded off, and the beginnings and ends of the pulses are shifted along the time axis. Distortion may also be caused by the different rates of propagation over a circuit of currents of different frequencies, but this is generally of less importance. In addition to the unequal attenuation that causes distortion, there is an overall attenuation that reduces the maximum signal strength.

At the distant end of the line the signal must operate electro-magnetic apparatus, which requires a certain minimum of current. With square signals this value of current is reached immediately, with the result that the duration of the signal received is the same as of that sent out. With the rounded signals, however, a variable time elapses before this required value of current is attained. As a result the duration of the signal is changed and it no longer correctly represents the signal sent. An ordinary relay-type repeater could rejuvenate the signals to the extent of sending out new square-wave impulses of the correct current value, but it could not restore the signals to their proper duration. After passing over several line sections, the signals might be so badly distorted that the teletype machine would fail to translate correctly the various pulse combinations that distinguish one character from another.

With the application of teletypewriter service to long lines, therefore, it became necessary to develop a regenerative repeater—a repeater that would send out a signal correct not only in magnitude but in shape and duration as well. This repeater, which has already been described in the RECORD,* was modeled on the dis-

*RECORD, *December*, 1928, *p.* 140.

*RECORD, *August*, 1930, *p.* 570.

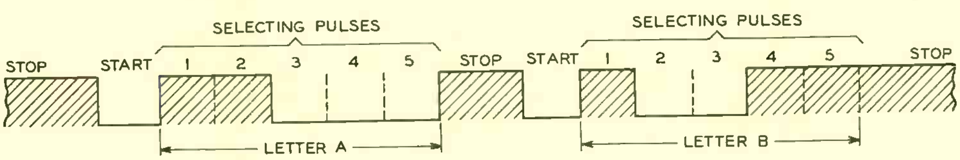


Fig. 1—*Letters A and B of the telegraph code* tributor used with the teletypewriter of that time. It consisted of a stationary plate carrying several sets of segments, and riding on the segments, rotating brushes which completed connections at the proper times to send out the rejuvenated signal.

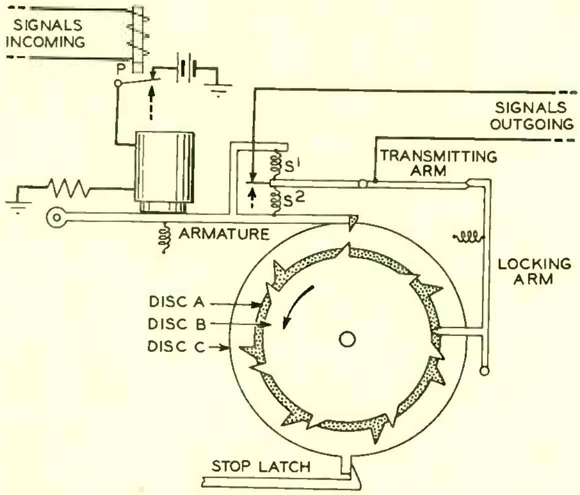


Fig. 2—The essential operating elements of the new regenerative repeater are a polar relay, a magnet and armature, a transmitting arm that sends out the signals, a locking arm that releases the transmitting arm at the proper intervals, and three discs that regulate the timing of the signals

These repeaters performed their function very well, and were capable of sending out correct signals when the received pulses were distorted as much as 40 per cent. With the rapid extension of teletypewriter service, however, and the use of the apparatus over longer periods of each day, it became apparent that some form of regenerative repeater that did not employ brush contacts would tend to provide more dependable service and lower maintenance charges. With this in view a new regenerative repeater has been developed which employs no brush contacts whatever.

The teletype code comprises signals composed of seven pulses—a start pulse, five selecting pulses, and a stop pulse. The start and selecting pulses are all of the same length, but the stop pulse, which is always a marking pulse, is about 1.5 times as long during continuous operation and is prolonged to cover the duration of idle periods. The start pulse is always a "spacing" pulse. The five selecting pulses may be either marking or spacing, and two or more consecutive pulses may be either all marking or all spacing, thus giving in effect a long pulse, or they may be alternately marking and spacing, giving short pulses. Figure 1 shows the signals representing the letters A and B, with a normal stop pulse between them and a prolonged stop pulse after the letter B.

The basic principle of all telegraph regenerative repeaters is to utilize only a small part of the middle portion of each received pulse to determine the nature of the outgoing pulses, and to control the timing of these outgoing pulses accurately by local means. In the new regenerative repeater a synchronous motor drives two sets of cams, the first set being used to pick out the mid portion of each incoming pulse, and the second set to control the timing of the outgoing pulses. The method of operation is indicated in Figure 2, which is a very much simplified diagram of the repeater unit. Three discs fastened rigidly together are connected to the synchronous motor through a friction drive. The motor runs continuously at the same speed as the motor at the transmitting station, but the discs are normally kept from rotating by a stop latch, and a pin on disc c. This latch is momentarily released, through a mechanism not shown, at the beginning of each letter signal, that is, at the beginning of the start pulse. The three discs then make one complete revolution, during which time a set of seven pulses will be sent out. At the end of the set of pulses, the latch will stop the discs from rotating unless a second set of pulses immediately follows.

The cams on disc A are in such positions with respect to the pin which engages with the stop latch that they cause the armature to be presented to the magnet about the mid point of each pulse interval. If the pulse is "marking" the magnet holds its armature in the attracted position. If the pulse is "spacing" the magnet is not energized so that the armature immediately falls back due to the tension of its restoring spring. In the "marking" or attracted position of the armature, spring s_1 is tensioned, tending to move the transmitting arm to its closed position as shown in Figure 2. In the "spacing" or unattracted position of the armature, spring s_2 is under tension, tending to move the transmitting arm to its open position. The transmitting arm, however, is not free to move until a cam on the B disc causes the locking arm to be momentarily withdrawn, when one or other of the two springs s_1 or s_2 immediately determines the position of the transmitting arm.

The method of operation will be seen more clearly by following through one set of seven pulses. Since the final pulse is always a marking pulse, the armature will be held up against the magnet at the time the new set of pulses begins, and the pin in disc c will be against the stop latch. This initial condition is shown in Figure 2.

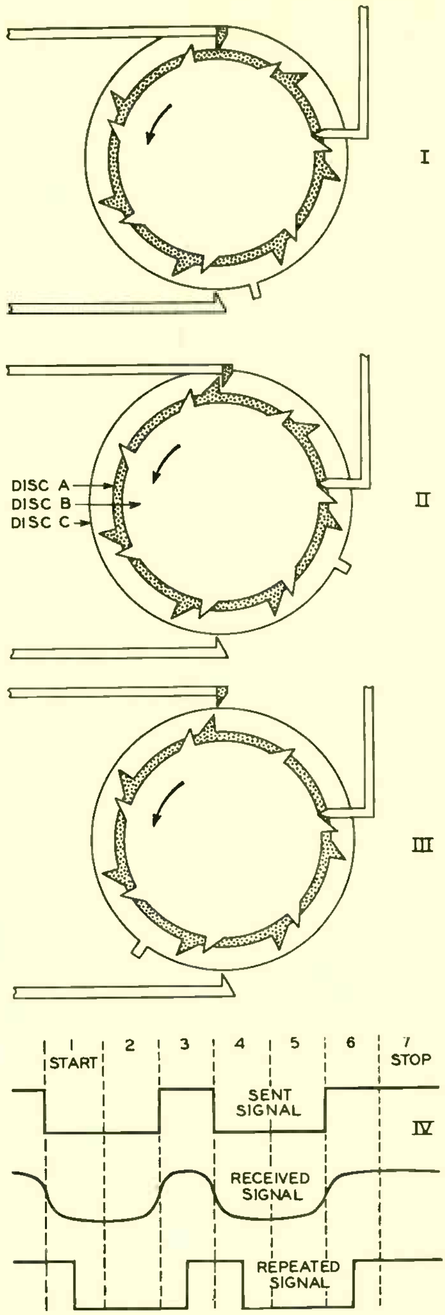


Fig. 3—At I—Start pulse just about to be sent by the repeater; II—Armature has just been raised before the sending of the second pulse; III—Stopping pulse just about to be sent; IV—top, a typical set of pulses from the transmitter; center, same pulses as received at repeater; below, pulses sent out by repeater with same form as those transmitted

At the beginning of a new set of pulses, the stop latch will be released, and the discs will start to rotate. After an interval slightly less than half the duration of a single pulse, discs will be in the position shown at I

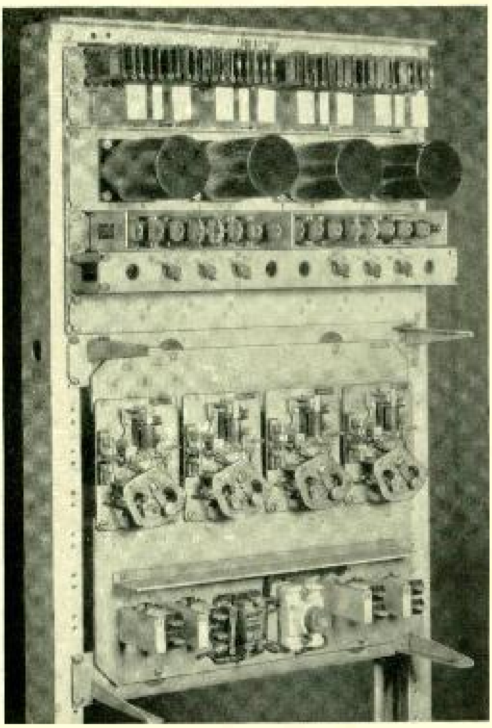


Fig. 4—A regenerative repeater unit for two 2-way circuits

of Figure 3. The armature will be down because the initial pulse is always a spacing pulse, and for this reason no cam on disc A has been provided at this position on the disc. The outgoing signals have not yet started, however, because the transmitting arm is still held up by the locking arm. A moment later, however, the first B cam will release the locking arm, allowing spring S_2 to pull the transmitting arm down and start the first outgoing pulse.

Just before the next B cam reaches the pawl of the locking arm, an A cam will have lifted the armature. Assuming that the signal being transmitted is shown by the pulses at the bottom of Figure 3, there will be no current in the magnet at this moment and so the armature will immediately fall back, and when the locking arm is operated, the transmitting arm will remain down to send the next pulse—which is also a space. Since the third pulse is a marking pulse, the armature will remain up when raised by the next A cam, and when the locking arm is next operated, the arm will move up to send a marking pulse.

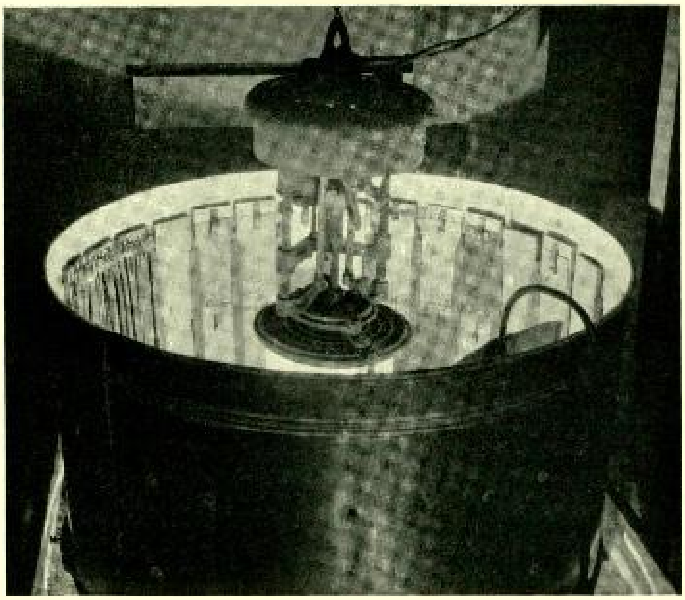
The following pulses are sent in a similar manner. A cam on disc A always raises the armature just before a cam on disc B actuates the locking arm. If current is flowing in the magnet when the armature is raised, a marking pulse will be sent, while if no current is flowing, the armature will immediately fall back, and the next pulse will be a space. The last, or stop pulse, is always a marking pulse and so the armature will remain up from the position shown at III until the discs are stopped by the stop latch.

It will be noticed that the locking arm is not operated to send out the first pulse until a short interval after the first pulse was sent out from the transmitting station. This is to allow time for a distorted signal to build up to its maximum value before requiring it to send current into the magnet. As a result, the set of outgoing pulses is always a short interval behind the incoming pulses in time, but the pulses are equally spaced square waves of the correct polarity because of the equally spaced B cams and the action of the armature of the repeater.

The signals leaving the regenerative repeater are always composed of make-and-break pulses, but they may be changed to other desired types of signal, such as positive and negative pulses, or carrier pulses by other apparatus at the repeater station.

This new method of regeneration adapts itself particularly well to a compact and economical equipment arrangement. The mechanical elements for four regenerators are mounted on a panel with a motor which drives all four regenerators through a drive shaft and spiral gears. Each regenerator may be removed for maintenance purposes without disturbing the others. This panel is floated on four rubber mountings which are in turn attached to mounting bars on a relay rack. Such a mounting arrangement prevents the vibration of the motor and drive from being transmitted to other equipment mounted on the same frame. Associated with each panel, and mounted above it on the rack, is a conventional relay-rack unit which carries the relays, keys, etc., required for the complete repeater. Such a unit, shown in Figure 4, comprises repeating equipment for two 2-way circuits. As many as four of these units may be located on an 11-foot 6-inch bay of relay rack.

One end of the Bell System exhibit at the Texas Centennial Exposition. Along the side of the wall are placed telephone receivers through which guests are listening to a demonstration long-distance telephone conversation. The architectural plans and the apparatus which are exhibited were developed in Bell Telephone Laboratories. The exhibit is operated by the Southwestern Bell Telephone Company



Automobile Finishes

By L. H. CAMPBELL
Outside Plant Department

WHEN the Bell System first had need of vehicles for transportation, the horse-and-buggy era was still with us and coach colors and varnish were the finishes employed. It was a job requiring several weeks to apply these finishes to the better type of horse-drawn vehicles. The materials had a natural gum and linseed oil base which was slow drying and required many coats, and with all this work the finishes did not last long as measured by today's standards. They weathered so poorly that they did well to get through one summer, or two at the most with good care. Moreover, the type of failure was deep seated because the finish checked and cracked instead of chalking or powdering like modern finishes. This often necessitated the removal of the whole paint film and a repetition of the painstaking procedure that had been originally required.

The old coach-varnish materials and their methods of application, with some slight modifications, were the accepted mode of finishing when the Bell System first began to use automobiles. The colors used for the most part were dull and drab, and the life of the average finish was not longer than that on the earlier horse-drawn vehicles. The paint failure usually started on the horizontal surface of the hood and on the cowl, and was evidenced by checking and cracking, which rapidly progressed to the rusting stage. This invariably took place on the early models during the second summer, and the only remedy was a complete stripping of the paint and refinishing. Later, black baking japans came into use, first on the fenders and later over the entire body. But this finish was available only in black and although more durable than the coach varnishes, as well as faster to apply, it was still too slow. It also required high-temperature baking ovens which made it costly. Moreover, its weathering qualities were not entirely satisfactory, particularly from an appearance standpoint, for in most cases the finish weathered to an unsightly muddy brown.

About a decade ago came the lacquer finishes first popularized under the trade name of "Duco" and with them the most revolutionary changes in the entire history of coach and car finishing. Gone were the slow and laborious methods, with their expensive equipment. Gone also were the depressing and melancholy blacks. For with the lacquers came the era of colors—colors to taste for pleasure cars, and individual and distinctive hues and shades for commercial vehicles. Examples of the latter are the Bell System standard green and standard blue-gray, and the characteristic reds, blues, browns and yellows that are used extensively by other commercial concerns.

Along with the aesthetic advances, came greatly improved methods of application as well as shorter drying time for the various coats. Furthermore, less sanding and rubbing was required. Also, the extensive factory space which was necessary for the slower drying materials was greatly reduced. This resulted in lower production costs for the finishes and at the same time gave coatings of greater durability so that today lacquer finishes are used on most pleasure cars.

The main steps in the application of a lacquer finish consist of applying first a linseed oil priming coat, next, a smoothly sanded lacquer surfacer coat, and finally finishing coats of colored lacquer which are then to be polished. The lacquer primers require such careful cleaning of the metal to obtain even passable adherence that they are not generally used commercially. Moreover, to obtain a really good adherence of any priming coat, the surface to be finished must first be thoroughly cleaned either mechanically, by sanding, or with chemical cleaners, such as phosphates, and then rinsed and dried. To obtain a smooth finish one or more coats of a lacquer-base product which carries excess pigment to give "building" or "leveling" qualities are applied. After a short interval for drying, such "surfacer" coats are sanded smooth, usually until the primer shows through at the high spots, since excess of "surfacer" tends to weaken the whole film. The final lacquer color coats are a mixture of the lacquer liquid and pigment, the former composed of nitrocellulose, gum, solvent, and an organic non-volatile liquid called a "plasticizer," which imparts flexibility to the dried film. Two or more coats of color lacquer are sprayed twenty minutes to a half hour apart. After two hours of drying, the whole is rubbed down and polished. The striping, which does all sorts of tricks in bringing out contours and generally enhancing the appearance, is then applied to complete the job.

When lacquers are used the finishing of a car requires a day and a half or less, as compared to the old coach varnish which required from ten days to several weeks. But the lacquer finish with all its advantages is not entirely satisfactory for certain types of service on telephone trucks and other commercial cars and in the refinishing shop. Further improvement was found in the four-hour enamels,

Fig. 1—*Wood and metal panels are prepared for exposure by the same finishing procedure as that used in painting automobiles*

brella handles, clocks, radio dials and vanity boxes. The new synthetic gums impart greater flexibility and give more weather resistance to the dried paint film, and when the film does fail it is by the chalking process—the least undesirable failure—rather than by cracking. The four-hour enamels can be either sprayed or brushed and their application involves approximately the same finishing steps as the lacquers except that the color coat dries to a full gloss and does not require rubbing and polishing. They are especially serviceable on commercial cars and lend themselves more readily than lacquers to refinishing over old paint coats. Selected four-hour enamels are now used for most of the refinishing work done by the Associated Companies.

Refinishing procedures, whether lacquers or enamels are used, vary with the condition of the old paint coat and the quality of the new finish desired. In some cases, although this is not recommended in Bell System practice, the old finish is merely washed and the color coat applied over it, without attempting to obtain a smooth under-surface for the new coating. The other extreme is to clean by "gas" sanding, that is, by dipping the sandpaper in solvent cleaner frequently while sanding to remove grease and oil and to prevent the paper from clogging; then to wash down and wipe dry, prime the entire job, putty damaged areas, sand smooth, and apply two or more color coats over all. Various compromises between these extremes are used. If

and while they are not as fast-drying as the lacquers, they are considerably faster than the coach enamels. They are superior to the lacquers in that they are uniformly successful on both wood and metal and can be brushed as well as sprayed. They dry with a gloss and do not require buffing and polishing. They are also more flexible than lacquer and are thus less prone to chip off in hard service; and they chalk less rapidly, which means that they require less maintenance.

The liquid or film forming parts of these enamels are, in the main, gums which have been synthesized by heating various chemicals. They are kin to the molded plastics now so familiar in fabricated articles such as umspray facilities are not available, a serviceable job of satisfactory appearance can be obtained with the enamels by "gas" sanding; "feather-edging" damaged areas, that is, sandpapering the broken edge of the paint film until it is thin; washing with a solvent cleaner and wiping dry; spot priming where the metal shows through; brushing on one or two coats of the new four-hour enamel and allowing to dry over night. If a good quality enamel is chosen, this is a quick and convenient method of dressing up the old car.

The four-hour enamels were not entirely satisfactory and a still faster finishing system was demanded which would also require the expenditure of less manual labor. These qualities were attained by the "one-bake" system. Like most other finishing procedures the "one-bake" system involves cleaning, priming, surfacing, sanding smooth, and applying color coats; but unlike the precursive enamel systems, all of the "one-bake" paint materials dry in an hour or less when subjected to a temperature of 225 to 250 degrees Fahrenheit. In applying them the primer and surfacer coats are each "force" dried half an hour to an hour at this temperature. The surfacer is then sanded and a thin or "flash" coat of color is sprayed on and allowed to air dry ten minutes. Then a heavier color coat is sprayed over it, after which one baking only suffices to dry both color coats and complete the finishing job, except for supplementary striping. The new one-bake system is being used almost exclusively for commercial cars and is beginning to invade the lower priced pleasure car field. All the new commercial vehicles and many cars of the supervisory fleet that are being used by the Bell System are now being fin-

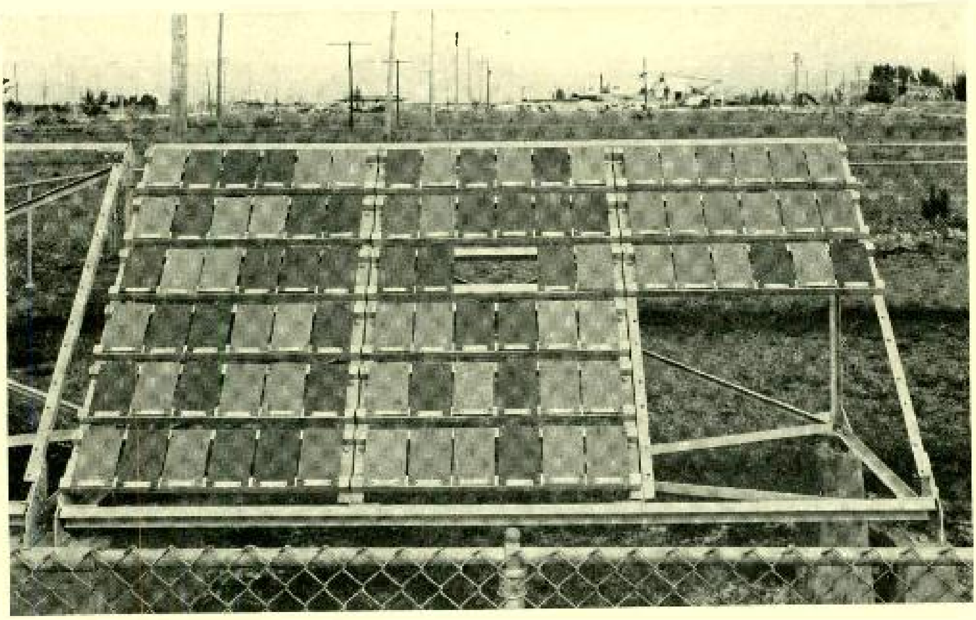


Fig. 2—The weathering qualities of automobile finishes are evaluated by subjecting test panels to accelerated exposure tests out of doors at Miami, Florida, and at the Laboratories. These tests are carried on for a period of from six to eighteen months

ished with these new forced dry enamels. These finishes are expected to be even more durable than any that have yet been offered to the motoring public. The natural gloss finish is not as pleasing as the deep, rich, satiny appearance of rubbed finishes but forced dry synthetics are new in the industry, and remedies for this and other minor imperfections will undoubtedly be forthcoming.

Since 1929, the materials and methods for finishing motor vehicles in the Bell System have been standardized and changes in the standards have been made from time to time as a result of testing available materials. The testing methods used are largely artificial weathering of painted panels, observation of painted panels exposed outdoors in New York and in Miami, Florida, and observations on how the materials handle in the practical painting of cars. The accelerated weathering is done in a "weatherometer"—a machine which exposes the test panels intermittently to water spray to simulate rain, and continuously to the rays of an arc light to simulate sunshine. Judicious use of the weatherometer has been found effective in distinguishing good automotive finishes from poor ones and in obviating further testing of the poor ones. Outdoor testing of the good finishes is the basis for selecting the ones most advantageously usable. Other tests* are also available to indicate the physical changes which take place in paint films exposed outdoors, and to predict their tendency to check, chalk, or peel in advance of such failures actually becoming visible.

Since the investigation was instituted the average life of the finishes used on the Bell System fleet has been more than doubled. In fact, the serviceability of finishes on the small commercial units is beginning to approach the useful life of the car, which is approximately four years. It now seems likely that this goal will be attained in the not distant future.

*RECORD, *January*, 1935, *p.* 141.

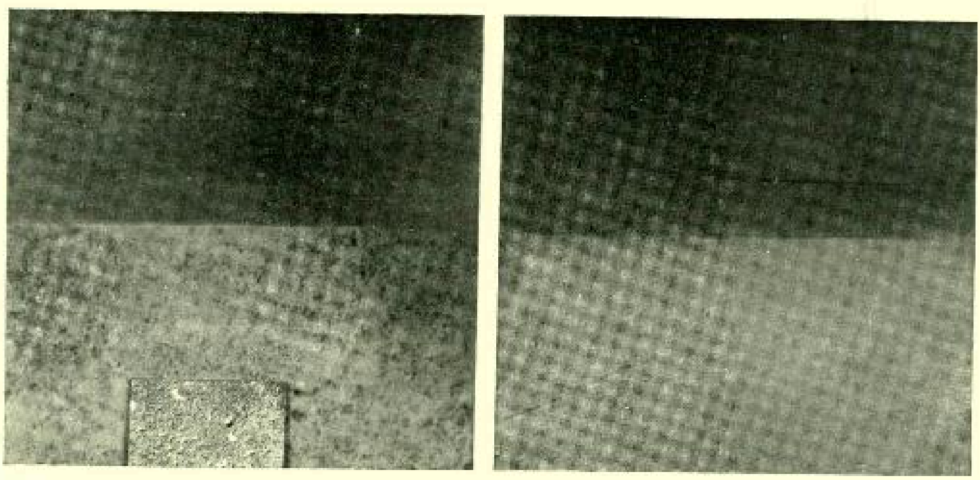
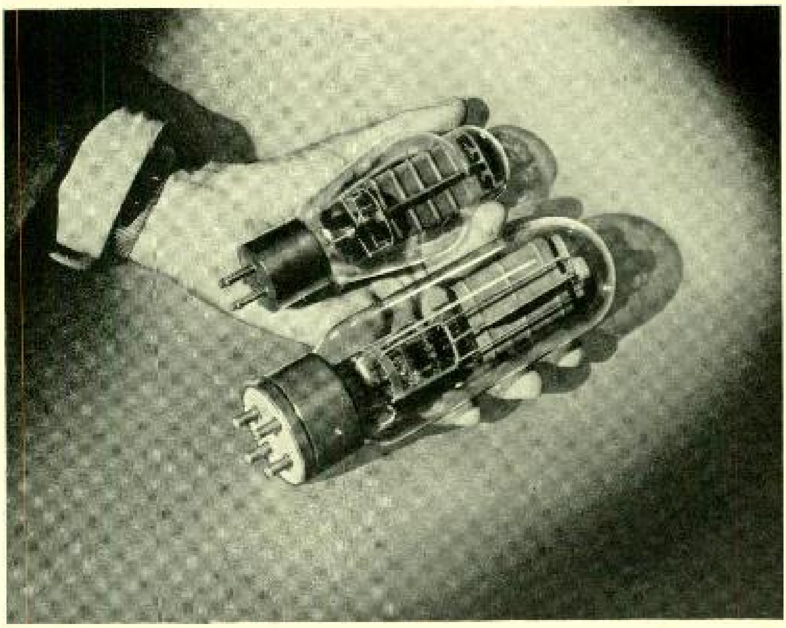


Fig. 3—Both of these panels had identical exposure to the weather. The left one shows the failure of an average enamel available in 1930 and earlier (the insert shows a magnified portion of the weathered paint surface) while the 1934 enamel on the right is still serviceable. The lower half of each panel shows the appearance when removed from the exposure rack; the upper half indicates the conditions after washing and polishing



The 300A Vacuum Tube

By J. O. McNALLY
Vacuum Tube Development

THROUGH the development of a new power vacuum tube—the 300A—improved amplifiers for sound-picture and public-address systems are now available at lower costs. One of the factors contributing to this cost reduction is a decrease in the operating plate voltage, which has made savings possible in the rectifier equipment contained in the amplifiers. This lower plate voltage has also made possible economies in the construction of the tube. This results in a lower maintenance cost due to the lower cost of tube replacements.

Improvements in the electrical behavior of the 300A tube are indicated by comparing its operating characteristics with those of the 242A tube. This latter tube is employed in the 43A amplifier, which is used at present in the majority of theatres equipped with Western Electric Sound Systems, while the 300A tube is employed in the 86A amplifier, which is designed for similar purposes. The comparison is given in Table I. The 242A tube requires a plate voltage of 800 volts, or over twice that of the 300A tube. The power output of the 43A amplifier is 12 watts whereas 15 watts is obtained from the 86A amplifier. The filament power required for the

TABLE I

Type Tube	242A	300A
Operating plate voltage	800	325
Operating plate current—milliamperes per tube	67.5	60
Power output in watts of two tubes in push-pull	12	15
Filament power in watts—per tube	32.5	6

Fig. 1—Disassembled elements of the 300A tube against a background of the same tubes on life test

242A tubes is five times that for the 300A tube. The comparative sizes of the two tubes may be seen in the photograph at the head of this article.

Like the previous tubes, the 300A is a triode. It has an oxide-coated filament which may be operated on five volts alternating current, normal filament current being 1.2 amperes. The plate is formed from sheet nickel, blackened by a carbonizing process to increase its heat radiating ability. Molybdenum wire, wound flat and welded to two nickel support wires, forms the grid. The general appearance and construction of the tube are shown in Figure 1, where the base with filament and grid structure are in the left hand, and the plate structure in the right. With a plate potential of 350 volts and a plate current of 60 milliamperes, the normal grid bias is −74 volts. A single frequency input of 74 peak volts will deliver 8.5 watts to a 3000-ohm resistance load in the plate circuit.

The ability to obtain large power outputs from the 300A tube with low plate voltages is made possible by the low plate resistance. This reduction in plate resistance has been accomplished by decreasing the amplification factor, by decreasing the spacing between elements—particularly that between filament and grid—and by increasing the area of the elements. The amplification factor has been reduced to the lowest practical limit, which is set by

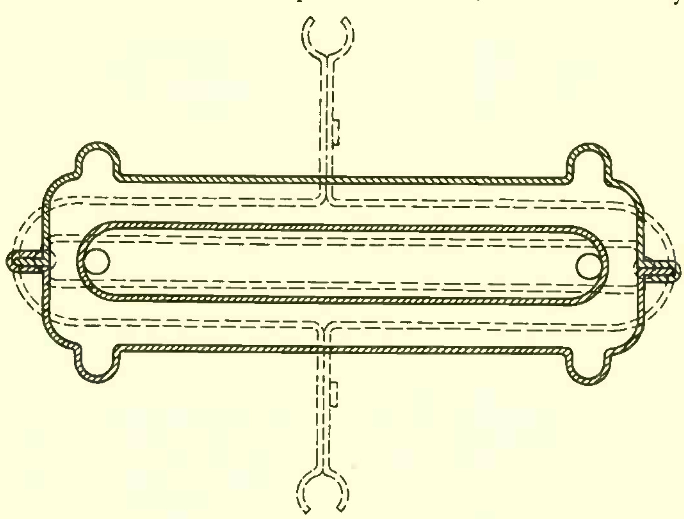


Fig. 2—A cross-section of the elements of the 300A tube, shown in dashed lines, superimposed on a similar cross-section of the 252A in solid lines, indicates one of the methods that were employed to decrease plate resistance

the point at which the varying current in the plate circuit ceases to be sufficiently linear with the input voltage, and causes distortion in the output.

How the inter-electrode spacing has been decreased and the areas increased is indicated by Figure 2, which shows a cross-section plan of the 300A tube in dotted lines, superimposed on that of the 252A tube, which is an earlier tube of approximately the same bulb size and developed for plate potentials up to 500 volts. It is capable of delivering only about one-half of the power of the 300A tube under similar operating conditions. The plate of the 300A tube has been widened in the direction of the plane of the filament, and the transverse spacing made less. To obtain the increased width of the plate without using a larger bulb, the plate construction has been changed. The two halves of the plate of the 252A tube are joined by flanges at the ends, and four support wires are fastened to the plate near the corners. In the 300A tube, the two halves are joined by wide flanges on the sides, to which the support wires are secured. This allows the plate to occupy the entire distance in width occupied by the plate and flanges in the 252A tubes, and has the additional advantage of stiffening the middle portion of the plate. The grid has been correspondingly widened in one direction and narrowed in the other to decrease the distance between the grid and filament.

Fig. 3—C. Depew tests tube for shock

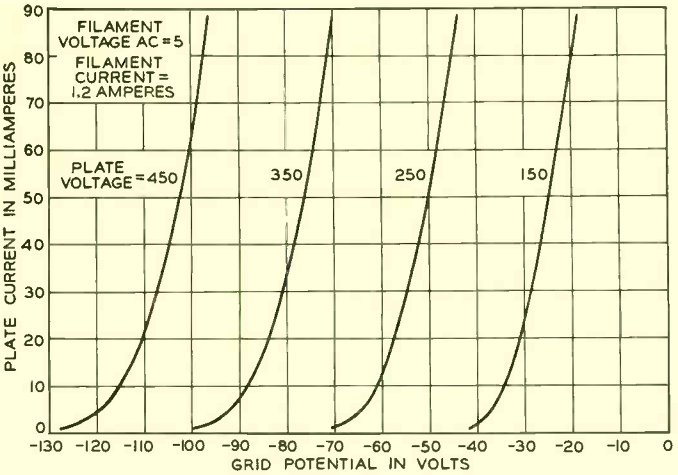


Fig. 4—Plate current and grid voltage characteristics

Beside these changes, it has been essential to have the filament extend the full length and width of the plate, so that the plate cur-

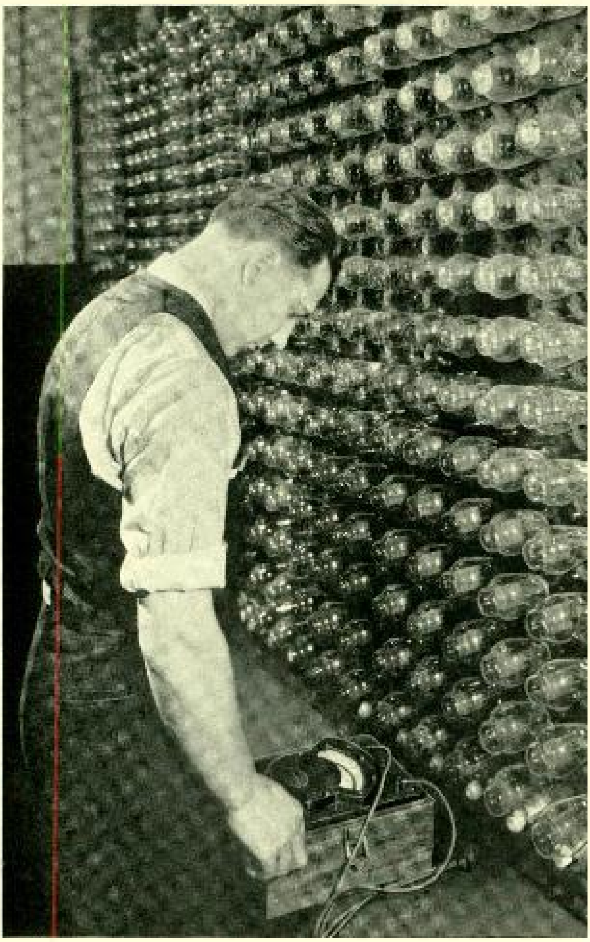


Fig. 5—L. G. Petrovich checking operating conditions of 300A vacuum tubes on life test

rent may be drawn as nearly as practicable over the entire plate area. This has been accomplished in the 300A tube by arranging the filament in a double M instead of the single M usually used. This is shown in Figure 1. The two M's are connected in parallel across the filament voltage supply.

In bringing the filament, grid, and plate closer together, the danger of short circuit from accidental physical contacts of the parts has been increased. Design features, such as the side ribs on the plates, and the rigid fastening of both ends of the support wires, however, improve the stiffness and offset this danger. The inherent stiffness of the tube elements is tested by attaching the tube to a cord and allowing it to swing as a pendulum against a stop in the center position. Such a test is shown in progress in Figure 3. The tube is drawn back to increasing angles and then released, and the angle at which failure occurs, as indicated by a relay circuit sensitive to short circuits of very short duration, is a measure of the stiffness of the elements.

Typical characteristics are shown in Figure 4. The output of the tube will depend, of course, on the plate and grid voltages selected. As the result of extensive life tests, it has recently been possible to raise the maximum operating plate voltage for the 300A tube from 350 volts to 450 volts. With 450 volts on the plate and a plate current of 60 milliamperes, a single tube will deliver 12.5 watts into a 4000-ohm load with second and third harmonics 26 db and 39 db, respectively, below the fundamental. Two tubes in push-pull may be expected to deliver 25 watts with harmonic levels of the order of 40 db below the fundamental.

Transmission Improvements in Telegraph Loop Circuits

By S. I. CORY
Toll Transmission Development

UNTIL comparatively recent years, transmission problems confronting telegraph engineers have involved to only a small extent the subscriber loop or local circuit connecting the subscriber station to the central office. Signalling speeds were low, from ten to fifteen dots per second, and since the loops were usually short and not exposed to interferences, they did not increase to any great extent the signal distortion caused by the main line circuits. Such distortion as was introduced could be partially or wholly compensated by adjustment of the telegraph repeaters at the central office, one of which was normally associated with each loop.

Due principally to changes in the character of telegraph service, the distortion introduced by subscriber loop circuits is now of much greater concern than formerly. Signalling speeds have been increased to twenty-three dots per second for much of the service, improvements have been effected in transmission over the main line circuits until the loop distortion has become a greater part of the total, and the circuits extend over greater distances and are more complicated. Moreover, for the most economical arrangement in switched teletypewriter service, it is desirable to use long loops—in some cases the length may be as great as thirty-five miles. In switched service, repeaters are not associated with each loop but are in the cord circuits used by the operator for interconnecting lines and loops. Since it is not practicable to readjust the repeaters for each connection, it is desirable to arrange the loops themselves so that they do not differ too widely in impedance and thus introduce only moderate distortion.

A typical arrangement of a loop circuit for a local connection in switched teletypewriter service is shown in Figure 1. As indicated, the loop consists of a pair of wires, which are usually in cable, extending be-

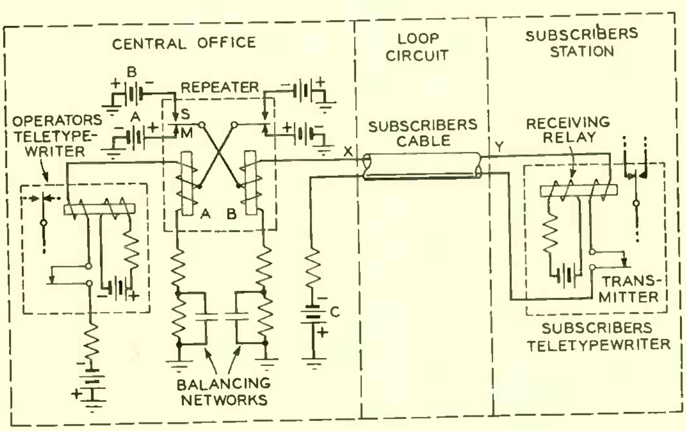


Fig. 1—Simplified schematic of a switched teletypewriter loop circuit between a central office and a subscriber station

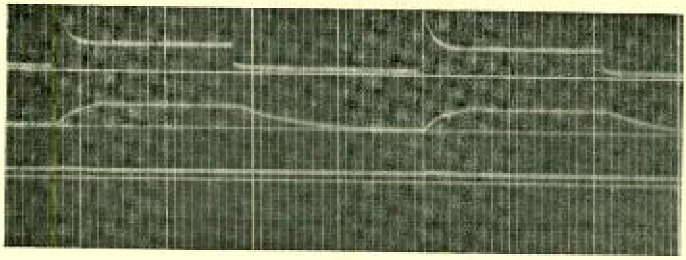


Fig. 2—Oscillogram of subscriber's signal over a long loop. The upper trace shows the signal at the subscriber's end while the middle trace shows the signal at the central office

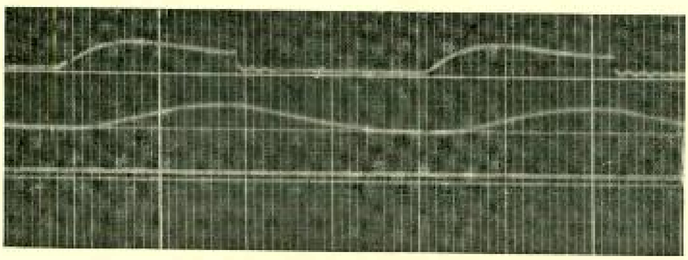


Fig. 3—Oscillogram of signal over the same loop as Figure 2 but with an inductance inserted at the subscriber's end

tween the central office and the subscriber station. At the central office the operator is connected to the loop at point x through a simple form of polar duplex repeater. The signals produced by the operator's teletypewriter cause relay A to connect alternately positive and negative battery through relay B to the loop. These "polar" signals pass over the loop and are received on the subscriber's apparatus which is directly in series in the loop. When the subscriber transmits, his machine opens and closes the loop, producing what are known as "open-and-close" signals. These signals operate relay B in the cord-circuit repeater at the central office, and this relay retransmits the original signals to the operator's teletypewriter.

These cable circuits, especially the longer ones, have considerable capacitance, and as a result certain transmission difficulties arise in operation. The general method employed in overcoming these difficulties consists in modifying the loop-terminating impedances so as to reduce the effect of the capacitance of the cable. This is done by properly distributing the current-regulating resistance for loops of moderate length and adding simple networks to the longer loops as required.

The signals from the subscriber station are distorted by the cable capacitance as indicated by the oscillogram of Figure 2, taken for a thirty-mile loop of 19-gauge cable pair. The upper trace shows the signal at the subscriber's end, and the trace below it, the same signal as it arrives at the central office. At the subscriber's end there is a sudden rush of current through the subscriber's relay as the circuit is closed, and then the current drops rapidly to its normal value, and remains there until the circuit is opened, when it abruptly falls to zero. At the central office the current rises fairly rapidly as the circuit is closed, and remains at normal value until the circuit is broken. It then falls off slowly as the capacitance of the loop becomes charged. The result is that the closed periods of signals received at the central office are longer than they should be, and the open periods are shortened. This discrepancy, or distortion, increases as the loop becomes longer.

This type of distortion is reduced by adding a suitable impedance at the subscriber's end of the loop (point Y of Figure 1). Such an impedance slows down the discharge of the cable as the circuit is closed at the subscriber's end, and thus retards the building up of the current at the central office. The effect is shown in Figure 3, which was taken for the same conditions as Figure 2 but with an impedance inserted at point Y of Figure 1. Because of the slow building up of the current at the central office—middle trace of Figure 3—the signal becomes more nearly symmetrical and the distortion is eliminated. If the loop is not too long the added impedance may be a pure resistance, but with a long loop, where the resistance is already high, this is not permissible because the operating current would be reduced below the desirable value. Where long loops are involved an inductive impedance having a low resistance must be inserted in the circuit.

The problem at the central office is somewhat different. As mentioned before, when the operator transmits, her signals cause the armature of relay A to move back and forth, thus connecting negative and positive battery to the mid-point of relay B and hence to the loop. It is essential, however, that relay B should not operate under the effect of these alternate negative and positive impulses. If relay B does operate, it sends a reverse current through relay A, which interferes with the transmission of signals by the operator's teletypewriter.

The upper winding of relay B is connected to the loop, which is closed through the teletypewriter at the subscriber's station, and thence to a biasing battery C at the central office. The lower winding is connected to a balancing network or artificial line, which ideally presents an impedance identical to that of the loop, and thence to ground. The effects in the relay windings when the loop and the balancing artificial line are pure resistances of equal value are indicated in Figure 4.

With positive battery connected to the mid-point of the winding of relay B, the current flow through the upper winding is just twice that through the lower winding and the direction of flow through the upper winding is such as to hold the armature of relay B in the position shown in Figure 1. The current flow through the lower winding causes an opposing magnetic effect and since it is only half as great, the net effect of the two windings is to hold the armature of B in the position which is shown.

With negative battery connected to the mid-point of the windings of B there is no current in the upper winding, and the current in the lower winding is reversed, so as to still give a force tending to hold the armature of B in the same position.

Although means are provided to adjust the resistance of actual cable loops to equal that of the balancing artificial line, provided the loop resistance does not exceed that of the artificial line, no means are provided to maintain an accurate balance between the capacitances of the loop and artificial line. As indicated in

MAGNETIC FORCE	POSITIVE TO B	NEGATIVE TO B
IN UPPER WINDING	↓ (long)	0
IN LOWER WINDING	↑	↓
NET EFFECT	↓	↓

Fig. 4—Magnitude and direction of magnetic pull of the two windings of relay B under the action of polar impulses

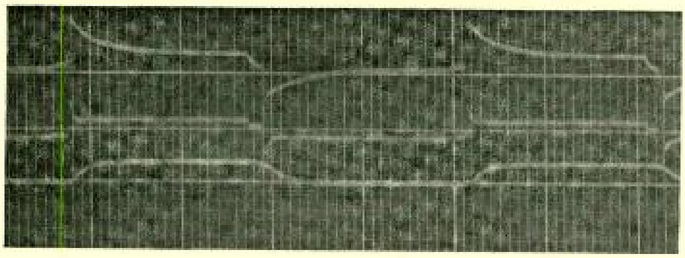


Fig. 5—Oscillograms showing current when the operator is transmitting. Upper trace, current in upper winding of relay B of Fig. 1; *middle trace, current in lower winding; and bottom trace, signal received by subscriber*

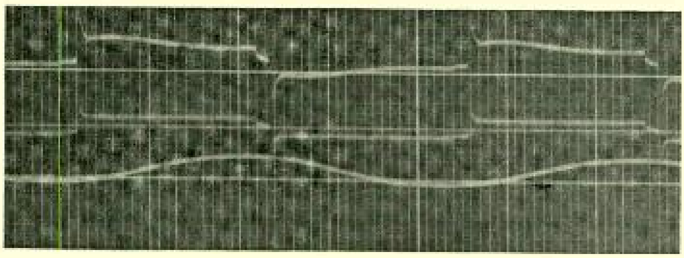


Fig. 6—Oscillograms corresponding to those shown in Figure 5, but taken after the insertion of the compensating network at the point X, shown at the center of Figure 1

Figure 1, a small capacitance is connected in the artificial line to obtain a satisfactory degree of balance for the shorter loops, *i.e.* those up to about eight miles in length. For short loops, the cable capacitance is less than that of the balancing artificial line, and with either negative or positive battery connected to B, the net force is still in a direction to hold the armature of relay B in the position shown. With longer loops, however, the loop capacitance is greater than that of the balancing network. Then with positive and negative battery applied alternately to the mid-point of the windings of relay B, the surges of current into the line are greater than those into the artificial line. With positive pulses the net force holding the armature of B to the positive contact is increased by these surges, but for the negative pulses the net force is decreased and may reverse, thus moving the armature to the opposite contact and interfering with transmission of signals over the loop. This condition is commonly referred to as "kick-off" due to duplex unbalance. An oscillogram showing the actual currents for a thirty-mile 19-gauge loop is given in Figure 5. The large surge current into the loop is plainly evident in the upper trace by the peaks at the beginning of each pulse. The current in the artificial line, shown in the middle trace, contains much smaller peaks. This means that there was considerable unbalance. Tests showed that the armature of relay B was "kicking-off" badly under this condition. The lower trace shows the current received at the subscriber station when the armature of relay B was blocked to its marking contact to prevent mutilating the signals to the subscriber station.

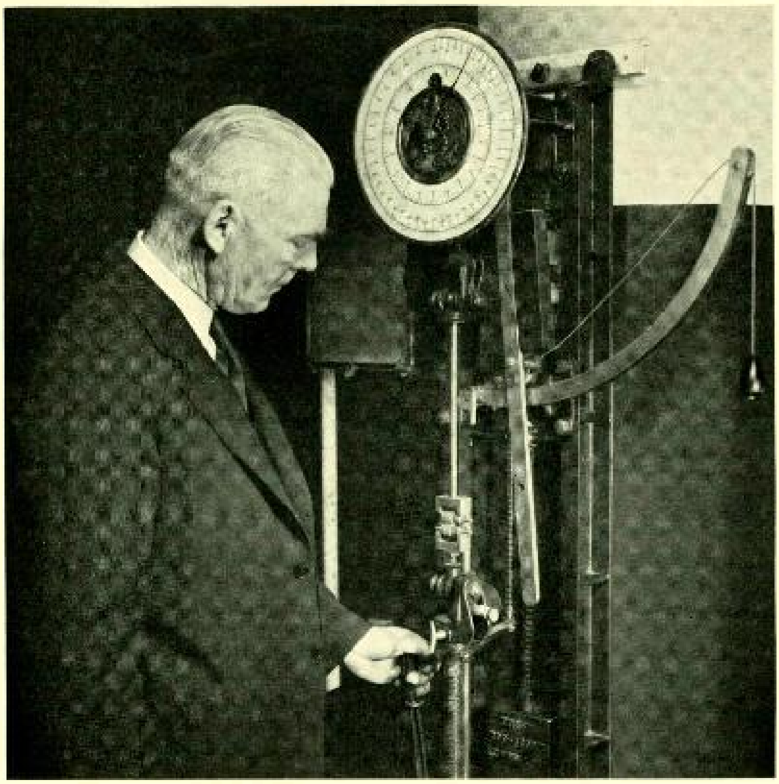
To reduce the effect of the cable capacitance so that a better balance exists between the line and artificial-line impedances, a small amount of resistance may be inserted at "x," Figure 1, when the loop is of moderate length and is not of too high resistance. For long loops a network consisting of resistance, inductance, and capacitance in parallel is inserted at "x." Oscillograms taken after the insertion of such a network are shown in Figure 6. Perfect compensation is not obtained but the initial surge of current has been decreased sufficiently to entirely eliminate kick-off. By comparing the lower traces of Figures 5 and 6 it will be seen that the addition of the network alters the shape of the signals received at the subscriber station, but this does not cause an undesirable distortion in the signals repeated by the subscriber's relay.

Prior to the application of this impedance-modifying method to switched teletypewriter loop circuits, it was not possible to give service to subscribers located more than ten or twelve miles distant from the central office unless additional repeaters were employed. In many cases this would have required special installations at considerable expense. With the impedance-modifying method, however, subscribers as far as thirty-five miles away may be connected to the central office over comparatively simple loop circuits. The results obtained in the application of this method to switched teletypewriter service have been so generally satisfactory that it is now being extended to private line service. While there is little switching necessary with these loops, the new method will effect economies, and will result in a general improvement in Bell System telegraph service.

"The telephone company has a remarkably well-organized process for attacking its problems as they arise or even before they arise. . . . Those fellows just started in to do certain things and did them. They have accomplished, in the course of two or three decades, improvements that would have come along only after thousands of years if there had not been an orderly pursuit of the answers to the telephone company's problems.

"Probably many of the telephone company's research discoveries are somewhat out of line with what one might suppose to be their primary purpose. Chiefly they are trying to find out how to give better telephone service, but their scientific exploration into their business future constantly is resulting in valuable surprises. This whole thing is comparable to Columbus setting sail to find a new passage to the Indies and discovering a New World. But you can be sure that before the telephone company got such an organized process for finding out things somebody had to have foresight enough to recognize the present and future problems."

—Charles F. Kettering,
The Saturday Evening Post, May 30.



Insuring Quality in Tapes

By W. H. S. YOURY
Outside Plant Department

FRICTION and rubber tapes are as important to telephone linemen, installers, and cable splicers as is turpentine to the painter or solder to the plumber. They are used daily in the installation of new plant, in maintenance, and in repair work. Friction tape, which many of us first used as youngsters to stop a leak in a bicycle tire or to recover a baseball, is a relatively strong cotton tape impregnated with an adhesive rubber compound that makes successive layers stick firmly together when wrapped around any object. Rubber tape, or splicing compound, as it is commonly called, is a ribbon of soft unvulcanized or partly vulcanized rubber, which also sticks to itself very tenaciously and becomes a solid mass of insulation as successive layers are wrapped around a wire.

These tapes are used for many purposes. Joints in drop wire, for example, are covered first with rubber tape to provide electrical insulation, and then with friction tape to afford mechanical protection and to exclude light from the rubber. The combination provides a covering comparable in properties to the rubber insulation and braid of the wire adjacent to the joint. The two tapes are also similarly employed for protecting temporary openings in lead-covered cables from damage by water. On inside wiring, where the joint will be exposed to relatively little moisture, a wrapping of friction tape alone provides all the insulating covering that is needed. Friction tape is also used alone for serving ends of wire or of manila rope to prevent raveling, for wrapping insulated wires where they might become abraided, and for other miscellaneous purposes. It is because of these many uses for friction tape alone that the amount of this tape used in the telephone plant is approximately five times that of the rubber tape.

Commercial types of tape differ greatly in their characteristics. Friction tapes vary from the so-called wet variety—which are very sticky or tacky—to the dry tapes, which have a relatively non-tacky surface. Rubber tapes vary from the soft, almost unvulcanized compounds, which are tacky and of low tensile strength, to the more vulcanized types of considerable tensile strength, which are not tacky. The most desirable type of tape depends upon the use to which it is to be put, and to insure the best possible tapes for the Bell System, the conditions of use must be studied, and then requirements specified that will insure a satisfactory tape under all normal conditions.

The important service requirements of friction tape for the Bell System are that the material must be strong enough not to tear when it is being wrapped tightly onto any object, and that it shall stay in place indefinitely after application. It is essential also that the tape surfaces have the qualities of adhesiveness and tackiness, which make the material relatively easy to unroll and apply whether it is freshly made or a year or so old.

Easy application qualities are particularly convenient when the friction tape is used to provide temporary protection for an unsheathed cable core that has to be left overnight until installation or repair work can be resumed. Figure 1 shows how the tape is applied by moving the roll so that while kept on edge, it is rolled around the cable core in a spiral path. Satisfactory wrappings are easily applied by this method provided the tape unrolls readily and provided its surface is sufficiently tacky so that successive layers of the tape adhere firmly under the light pressure which results from the easy unrolling. The illustration also shows the fingers of one hand picking the edges of the tape wrapping to check whether or not the

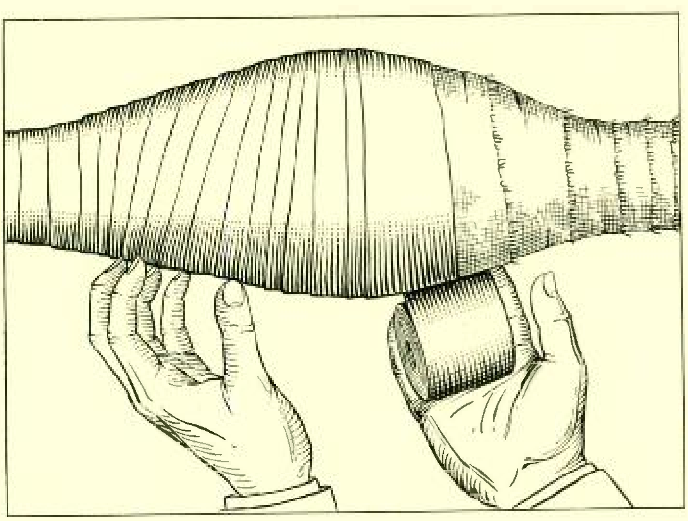


Fig. 1—Method of wrapping friction tape on a splice

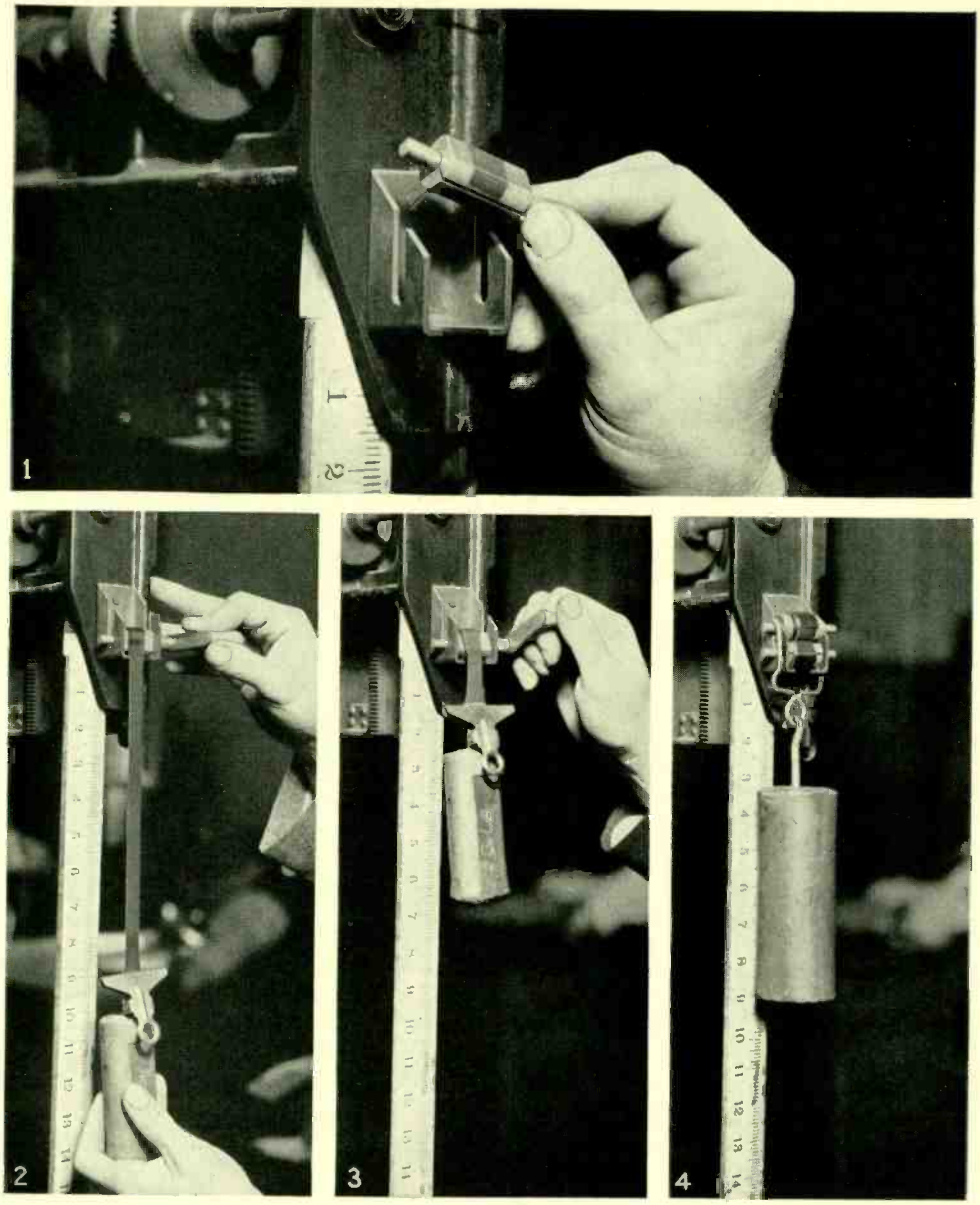


Fig. 2—Top: One of the two mandrels used for adhesion test of rubber tape; Left, the tape is first stretched to three times its original length; Center, the tape is then wound on the mandrel under a prescribed load; Right, two of the mandrels so wound are then pressed together at a specified pressure and for a specified time

tape adheres well to itself. Due to the fact that rubber tape is extensively used to wrap joints in wire used outdoors, it needs to have handling qualities which facilitate application as a relatively smooth built-in-place rubber insulation which is free from unclosed passages through which water might enter. The stretchable character of rubber tape enables it to be wound on an irregularly-shaped joint without leaving cracks under the edges of the tape. This need for tightly sealed rubber tape wrappings is an important reason for the disfavor of "combination" tapes in outside plant use. One wrapping of the "combination" tapes, which are made with a rubber tape surface on one side and friction tape on the other, is designed to take the place of wrapping with the two kinds of tape separately. The "combination" tapes, however, have the non-stretching character of friction tape.

Certain specification requirements are framed primarily to control the handling qualities of both friction and rubber tapes. These requirements limit such things as tensile strength, elongation, and tackiness, that is, the ability of tape surfaces to adhere when pressed together lightly. Other requirements, intended chiefly as criteria of the serviceability in the telephone plant, are those limiting adhesion: the force required to pull the tape surfaces apart after they have been pressed together about as tightly as they would be in practical use. Tests for tackiness and adhesion are made on both kinds of tape as purchased and also after an accelerated aging treatment.

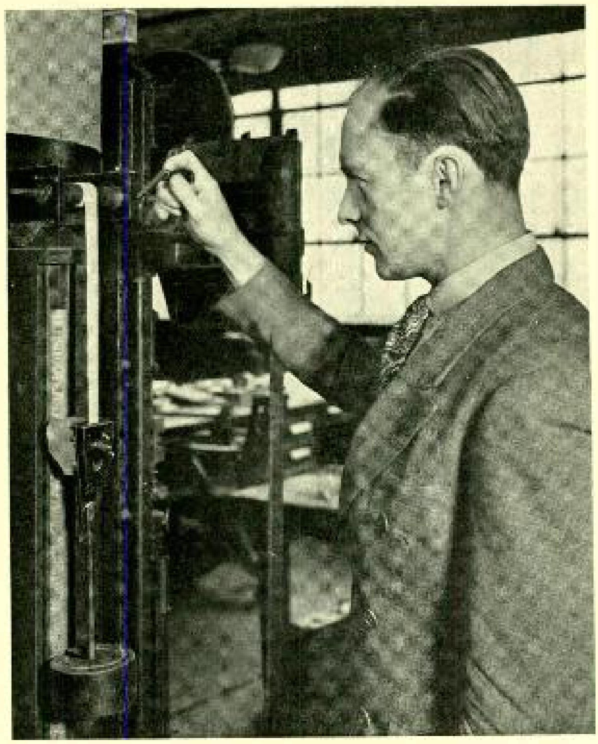


Fig. 3—J. J. Bace of the Western Electric Company making an adhesion test of friction tape

The adhesion of friction tape is determined by the use of the apparatus shown in Figure 3. A strip of tape is wound on a mandrel under a specified tension, produced by a weight hung from the end of the strip. After the tape is fully wound up, it is held under winding pressure for a specified time, and then the winding weight is replaced by a lighter one, giving a load of four pounds per inch of width, and the roll is allowed to unwind under its action. The distance it unwinds in one minute, measured on a scale attached, is a measure of the adhesion.

This comparatively simple method of measuring adhesion is not entirely satisfactory for rubber tape, because when layers of rubber tape are pressed together, the surfaces in contact practically fuse together, and the force required to pull them apart is affected by the stretching of the tapes as their surfaces are separated. The apparatus and method developed in the Laboratories to minimize the variations in testing the adhesion of rubber tape are shown in Figure 2. Each of two small cylindrical mandrels cut flat on one side are first wound with four layers of the tape stretched to three times its original length and wound on under the tension of a definite weight. Then the two flattened sides are pressed together under a specified load and for a specified time. Following this they are removed to a tensile testing machine, and the force required to pull them apart is taken as a measure of their fusion.

Tests for tackiness are not, and need not be, so definitely quantitative. A rough evaluation of the tackiness of friction tape is obtained by holding the two ends of a strip a few feet long, and then flipping the surfaces of the tape into contact. After this very light contact they should stick together with appreciable force, which is judged by the effort required to pull them apart. One surface of the tape usually differs from the other in tackiness, and the test is made for the three possible side-to-side combinations. For at least two of these three conditions sufficient tackiness must be found if the tape is to be accepted as satisfactory. Tackiness of rubber tape is evaluated by stretching the tape to three times its length, winding it under tension on a mandrel and noting if there is a tendency for the winding to unroll when the tension is released.

It is just as important for tapes to have satisfactory characteristics a considerable time after manufacture as it is to have them good when new. For this reason the Bell System requires that tapes meet a set of requirements after a specified aging procedure. In general, the aging of tapes is greatly accelerated by high temperature, exposure to sunlight, or contact with air with an appreciable ozone content. Many types of aging tests have been employed by the Laboratories in their studies of tapes. The test employed for inspection purposes, however, consists in storing the rolls of tape for four days in a temperature of seventy degrees Centigrade. Studies have shown that tapes having satisfactory qualities after this aging procedure will also be satisfactory for plant use after more than a year of ordinary shelf storage.

Most commercial tapes are wrapped in waxed paper, metal foil, or cellophane, which besides making a more attractive package is presumed to give better shelf aging. Experimental work in the Laboratories, however, has not substantiated this belief, and consequently no such wrapping is required for the Bell System. Each roll is packed in a cardboard container and no other wrapping is required. Both rubber and friction tape are supplied in three widths, ¾ inch, 1 inch, and 2 inches. Friction tape is supplied also in four colors. Black is the one most commonly used, but gray, ivory, and dark brown are available where color matching is desirable. Since the rubber tape is almost invariably covered with friction tape, color is of little importance and is not specified. It is usually gray or black. Two sizes of rolls are used for friction tape—36 and 75 feet respectively. The smaller roll is particularly useful where space is at a premium, such as in wrapping aerial cable where the roll must be passed between the cable and the messenger. Rubber tape is not supplied in rolls of more than thirty feet, since larger rolls would be too bulky.

It would require from fifty to one hundred fully loaded five-ton trucks to carry the friction and rubber tape used annually by the Bell System. The quantity purchased in any one year, if in ¾-inch width, would make from five to ten strips across the entire breadth of the United States from New York to San Francisco.

Contributors to This Issue

J. H. Bell spent over two years in South Africa with the Signal Corps of the British army during the Boer War and in 1902 went with the Engineering Department of the British Post Office. He left to join the Western Electric Company at West Street in 1911. Since that time he has been with the Laboratories continuously, engaged in telegraph development work and such allied systems as picture transmission. At the present time he is in charge of telegraph development.

L. H. Campbell, after graduating from Bucknell University in 1920 with an M.A. degree in Chemical Engineering and spending two years as an assistant analytical engineer with the Carnegie Steel Company, came to the Laboratories in 1922. For six years he was assistant in charge of the analytical chemical laboratory in the Research Department, after which he became engaged in research work on paints and related material. In 1929 he transferred to the Outside Plant Department where he has since been concerned with the engineering features involved in providing protective coatings for outside plant equipment, writing specifications for these paint materials, and preparing Bell System Practices to guide the field in their use.

J. B. Bishop received a B.Sc. degree from Acadia University at Wolfville, N. S., in 1921. He then spent two years at Yale as a graduate student in physics, and the following three years at Cornell—both as graduate student and instructor in physics. In 1926 he received his Ph.D. from Cornell, and immediately went with the Westinghouse Lamp Company as Vacuum Tube Development Engineer. In 1928 he joined the Radio Development Department of these Laboratories. Here he initially spent some time in studying the dynamic behavior of radiation-cooled vacuum tubes, but for the most part he has worked on the design of radio transmitters for aircraft service.

W. H. S. Youry received the degree of Electro-Metallurgy from Lehigh in 1920. After a year with Westinghouse Lamp Company, he joined the Technical Staff of these Laboratories where he was associated with the Engineering Inspection Department. In 1927 he transferred to the Outside Plant Department with which

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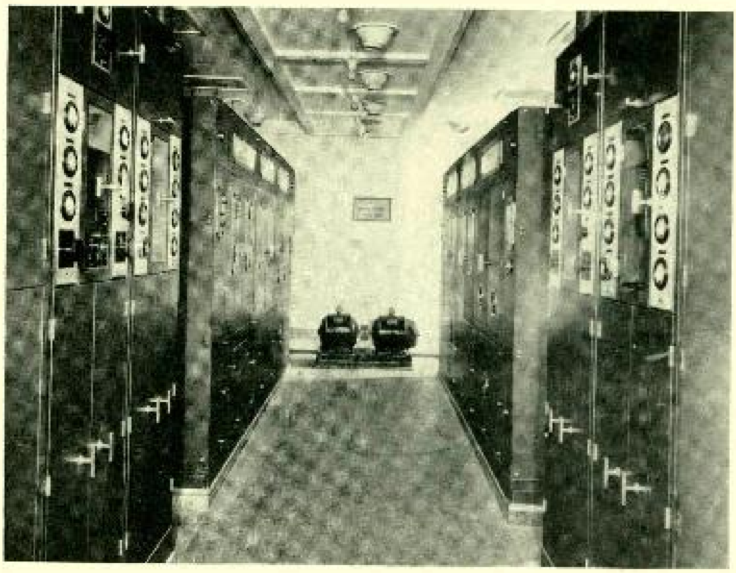
S. I. Cory

J. O. McNally

he is still affiliated. He now has charge of the Miscellaneous Group.

S. I. Cory received the degree of B.E.E. from Ohio State University in 1916, and immediately joined the Engineering Department of the American Telephone and Telegraph Company. Three years later he transferred to the Department of Development and Research, coming to the Laboratories in 1934. During this entire time he has been in transmission development work, chiefly on telegraph systems and transmission-measuring methods.

J. O. McNally received the B.S. degree from the University of New Brunswick, Canada, in 1924, and immediately joined the Technical Staff of the Laboratories. With the research department his work has been entirely devoted to the design and development of vacuum tubes and to the study and analysis of vacuum tube problems in general.



Radio room of the Queen Mary showing her two high-frequency transmitters, supplied through the International Telephone and Telegraph Company