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To The Men and Women of Bell Telephone Laboratories

A year ago I ventured to look into the future of 1928 *and to see there a picture of achievement of interest to us all. The accomplishments of the twelve months just past have fully justified that picture. As we come once more to the turning of the page to another new year, one and all we are curious as to what we shall find there.*

Viewing the vast array of problems which confront us — problems which arise out of the irresistible pressure in the Bell System for enlarged service or from those great new industries which are building on the basis of our work — it is clear that we have a job to do in 1929.

For twenty-five years I have been a part of the research and development organization of the Bell System. In all that period there has never been a time when the work immediately ahead bulked so large either relatively or absolutely. The problems which now confront us are numerous, vast and intricate almost beyond belief. Their solution will tax to the limit our ability, ingenuity, organizng capacity and energy.

None of us is afraid of such a challenge; and since the substantial satisfactions of life are the memories of constructive work well done, we can one and all welcome the opportunity to show what manner of men and women we are.

My greetings of the Season are tempered by the sadness which we all feel at the sudden and untimely loss of our friend and associate, Vice-President Clifford.

FRANK B. JEWETT.

Particles and Waves

By KARL K. DARROW
Research Department

WHEN we read in the morning paper that it rained yesterday in Chicago and the day before in North Dakota, and presently look out of the window and see clouds gathering in the Western sky, we think it natural to say "the rain is arriving from the West." This, however, is loose language; but to say precisely what it is that is arriving from the West would require more knowledge than most of us possess, more perhaps than the greatest weather experts can justly claim. Certainly the water which is about to descend into the streets of Manhattan was not over Illinois yesterday. Probably it was suspended not many miles away from New York as invisible vapor in the sky, when the air suddenly grew cooler and it began to condense into visible cloud. What came from the West at the speed of an express train was not the substance of the cloud, but the fall in the temperature of the air, or some other state of the atmosphere, which created the cloud in its footsteps as it raced along. Rain, of course, is more intelligible. What goes from the clouds to the pavements is matter in motion, individual corpuscles of water which go as units through the air until they splatter upon the ground or are swallowed up into the rivers. When a raindrop falls into water, its identity is gone forever; but for a time there are ripples spreading in widening circles over the water-mirror from the place where the drop ceased to exist. The ripples seem to have inherited the motion of the raindrop; but their onward march is not motion of substance. The water is not flowing away from the place where the raindrop perished; the water is only heaving up and down; what moves away is a mere form or molding of its surface, even less palpable than the travelling fall in temperature which brought about the coming of the rain.

Now this little history of the rainstorm exhibits three kinds of motion only one of which is strictly motion of matter; and since the study and the forecasting of motion is one of the major objects of science, we find here three problems to set before the architects of physics. Only the second of the three was solved by Newton in his masterpiece, the *Principia*, in which he founded the "classical" mechanics. The "Laws of Motion" which Newton gave as the foundation for mechanics were laws of the motion of matter. He solved, for instance, the problem of the projectile, and traced the path for the cannonball to follow after it leaves the cannon's mouth. Were it not for forces, Newton said, the ball would continue onward in a straight line forever; but the earth exerts a force upon it, and so it bends its course along an arc which brings it back to earth again in the predicted spot. The roar of the gun, however, is not a piece of metal, but a wave; and its motion is not subject to the laws of Newton.

Examining, however, the journey of the roar of the gun, one finds that it is not altogether unlike the journey of the ball. We know—though the knowledge was not available to Newton—that the sound of the shot, having risen into the sky, may bend over and come down again to earth at a great distance, so that beyond a broad zone of silence the gun is audible. Could we make visible the track of a particular section of the wavefront of the explosion-wave, a section starting nearly vertically upward, we should occasionally see it as an arch in the high air, like though not exactly the same as the arched trajectory of the cannonball. Short radio waves have at times the same habit of rising up from the broadcasting aerial, overarching wide tracts of land where it is vain to try to detect them, and descending to be received by listeners far away.

Now it is said that the cannonball descends because the earth pulls it downward out of the straight course which it otherwise would follow into the depths of space. Are the waves also drawn downward by some force out of a straight path in which otherwise they would continue? It is not necessary to imagine such a force; it is sufficient to recall that the speed of the waves varies from point to point in the air. At times the air is warmer several miles overhead than near the ground. When a section of a wavefront ascends obliquely into this warmer stratum, its higher part advances faster than its lower part, and the wavefront is tilted gradually over—one might say that at the start it is leaning backward, and bends forward, eventually standing vertical, then leaning forward and finally plunging downward to earth. The radio waves which "skip" long distances behave in the same way: their wavefronts are gradually tilted over and down because they move faster in the upper air than in the lower, though the cause of the greater speed in the higher atmosphere is not increase of warmth but an abundance of free electrons. For the same reason light is refracted when entering water obliquely from air; the part of the wavefront which is first to dive is also first to be slowed down, and the whole wave is wheeled around until it moves in a direction more nearly perpendicular to the interface of air and water.

Different reasons, therefore, are given to explain why waves on the one hand, projectiles on the other, deviate from the straight course: the "cause" in the one case is described as a variation of the wave-speed from point to point in the medium, in the other case as an external field of force prevailing at every point of space. Now when we come to express these two explanations in mathematical form we find (as not infrequently happens in mathematical physics) that the two sets of equations display strong resemblances, which are not in the least evident to a mere casual contemplation of the seemingly very different pictures which they describe. The picture of an external force-field and the picture of a variable wave-speed are in essence much more alike than they seem. Indeed it is permissible to say that the cannonball, travelling along its parabolic arc from the cannon's mouth into the sky and back to the ground, is riding upon an invisible wave which carries it along like a parcel; the motion of the ball is controlled by the motion of the wave, which is determined by the variation of the wave-speed from point to point. It is easy to formulate the way in which the speed of this imaginary wave must depend upon height above the ground-level, in order to explain the motion of the projectile. One of the Bernoulli family did it more than two centuries ago. One might imagine the space around the earth to be filled with an aether, able to carry waves with a wave-speed prescribed in the proper way; the firing of the gun would be supposed to create a mighty wave, which carried the projectile on its back. There would have to be a different aether for every different choice of initial velocity for the cannonball, which makes the picture rather clumsy; yet it might present advantages great enough to make even this clumsiness endurable.

The waves of the foregoing picture are not precisely the waves which de Broglie invented and Schroedinger adapted, thus founding the new "undulatory mechanics" or "wave-mechanics"; but the two kinds are sufficiently alike for either to serve excellently as an introduction to the other. As a matter of fact, the "de Broglie waves" for the cannonball trace the proper parabolic arc, but move much faster than the ball, which therefore cannot be thought of as riding upon them. (The speed of the ball is the "group-speed" of the de Broglie waves—a concept which however is a little too intricate to be explained here, although it is familiar in optics). The waves of de Broglie and Schroedinger are endowed, however, with another feature, which I will now illustrate by an example from acoustics.

Suppose a tensed piano-wire infinitely long; suppose it plucked at a certain point, or preferably set into continuous simple-harmonic vibration by a tuning-fork pressed against it. A wave of distortion starts from the place where the sidewise push or pull is applied, and travels indefinitely along the wire with a constant speed. Suppose now that the length of the wire is limited, say by cutting it in two places and attaching the ends firmly to walls. We will suppose for convenience that the tuning-fork is pressed against the midpoint of the wire between the walls. The waves travel from the fork along the wire to the walls, are reflected, return, meet new waves and combine with them, are again reflected from the opposite walls, meet additional waves and coalesce with these, and so forth; and eventually a "steady state" is attained, in which the motion of the wire is in general very complex. It is, however, a matter of common knowledge that if a certain condition is satisfied—if the frequency of the tuning-fork is properly adjusted to the length of the wire and to the speed of the waves, which last is determined by the tension of the wire—then the motion of the wire becomes both simple and vigorous. If, for instance, the frequency of the fork is made equal to the "fundamental frequency" of the wire, which can easily be computed from its length and from the wave-speed, then the particles of the wire vibrate with an amplitude which increases steadily from both ends to the centre. A loud musical tone is heard from the wire, and to the eye it seems to be spread into a ribbon of which the breadth varies as a sine-curve, or rather would so vary if the force were properly applied. This "ribbon" is a wave-pattern; and when the frequency of the fork, which is the frequency of the waves, is adjusted to agree with any one of the natural frequencies of the wire—its fundamental or any overtone—a wave-pattern characteristic of that frequency appears. This is called the phenomenon of *resonance.* A like effect would occur if the wire were bent into a closed ring. Here resonance would take place when the frequency of the waves was so adjusted that each wave on completing the circuit found another just starting on the course.

Frequency is the new feature which de Broglie introduced into the waves which I earlier mentioned, the "phase-waves." Frequency implies the possibility of resonance; frequency implies diffraction, interference, perhaps polarization, a variety of properties of light and sound which could be looked for and might be found. Suppose, for instance, that the Bernoulli waves which I described at first, which may be conceived to carry the cannonball in its flight, were endowed with a special frequency and wave-length; might it be possible to generate them inside a box of dimensions so chosen that they would enter into resonance, and the resonance be detected in some peculiar way? The idea seems a wild one; but the atom-model of de Broglie and Schroedinger is developed from one like it.

For twenty years it has been accepted that a hydrogen atom is composed of a positively-charged nucleus and an electron revolving around it, sometimes in a circular orbit. In order to explain the properties of this atom, it is necessary to assume that out of all the infinity of conceivable circular orbits of various radii, only a few are "permitted" to the electron; we know which these permitted ones must be. Now let us follow de Broglie and correlate with the electron a stream of waves. Like the Bernoulli waves they shall rush around and around the orbit of the electron, but unlike the Bernoulli waves they shall not have its speed. Their wave-speed shall depend upon distance from the nucleus of the atom, as the speed of the Bernoulli waves associated with the cannonball depended on height above the ground, although not according to the same law. The choice of the law of dependence of the wave-speed upon the distance is the chief step in the design of the atom-model; one might envisage it as the invention of a special kind of aether filling the space in and around the hydrogen atom, designed to carry waves with a wave-speed varying from point to point according to a law specially chosen. Finally, these electron-waves shall have a special frequency, proportional to the energy of the system composed of electron and nucleus, which is the atom itself.

When all these assumptions are made, and the law of the wave-speed properly chosen, it turns out that the permitted circular orbits are precisely those on which the electron-waves so overlap one another that they form a stationary wave-pattern, and resonance occurs. Were we to take a circular orbit at random we should probably find that the overlapping was such as to produce a very confused and intricate vibration, like the motion of a piano-wire forced to vibrate by a fork not tuned to any of its natural frequencies. But for the permitted circular orbits the wave-motion in the imaginary aether pervading the hydrogen atom is of the simple character of the motion of the wire stimulated by a fork having one of its own natural frequencies.

Viewed in this way, the problem of

the atom becomes the same as the great problem of acoustics: to find the natural frequencies of a body capable of vibration. The problem of the oscillating electron becomes like that of the piano-wire; the problem of the revolving molecule like that of the telephone-diaphragm; the problem of the hydrogen atom like that of the ball of fluid. They are more intricate than their acoustic analogues, for in the wire or the sphere of fluid the wave-speed of the sound-waves is everywhere the same, while in the "imaginary string" used as symbol for the oscillating electron and in the "imaginary fluid" used as model for the hydrogen atom, the wave-speed must be supposed to vary from point to point in a peculiar and characteristic way—the selection of this way being, as I said before, the chief step in the building of the theory. *En revanche,* this variability of wave-speed is precisely what makes the problems soluble. When we are dealing with an actual wire, membrane or fluid, we get resonance only when they are bounded—when the wire is cut off and clamped at the ends, the membrane cut into a circuit and clamped around the edge, the fluid contained within a rigid hollow sphere. But the imaginary strings and membranes and fluids of the atomic theory have resonances even though they continue to infinity; and these resonances correspond to the Stationary States of the atoms, from which most of their qualities are derived.

One more example: if an electron is attended by waves moving along the same path, and a beam of electrons moving along parallel lines is therefore escorted by a beam of parallel waves, may not these waves be diffracted by a grating as light-waves are? and may they not carry electrons into the diffraction-fringes as Bernoulli's waves were thought to carry the cannonball (though here again the speeds are not equal), so that in effect the electrons will be diffracted? On computing the wave-lengths which, in order to make the model for the hydrogen atom valid, must be assigned to electrons of given speeds, it is found that those associated with electrons of the speeds ordinarily occurring in discharge-tubes are of the magnitude of the wavelengths of X-rays. We must, therefore, use natural crystal gratings such as are used with X-rays. Carrying this idea (which first occurred to a young German student named Elsasser) into practice, Davisson and Germer discovered that electrons are in fact diffracted as are waves of the calculated wavelength.

We are therefore confronted with the amazing fact that the phase-waves, conceived purely as a mathematical artifice, seemingly differing from matter and electricity as the visions of the mind differ from the common-sense actuality of the solid physical world, have nevertheless acquired a reality ranking with the reality of things visible and things tangible. Indeed theirs may be even the stronger; for when the equations describing the resonances of the hydrogen atom are actually derived and written down, the electron and the nucleus are no longer obvious in them, and nothing remains but the wave-pattern. It is as though at a concert the air which carries the music and the instruments of the orchestra and the players themselves should be proclaimed unreal, and nothing remain but the music.

Transmission Regulating System for Toll Cables

By E. D. JOHNSON
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EXPOSED to sun, wind, rain and sleet, an aerial telephone cable varies in temperature over a wide range. Changes result in resistance of the conductors and, to a lesser degree, in dielectric capacity, with accompanying changes in attenuation of the speech currents. For the cables in the exchange plant, and for the shorter toll cables, these changes may be disregarded, but for the long toll cables they make necessary frequent readjustment of repeater gains to keep the net loss of each circuit within the rather close limits specified. The readjustment is effected by an automatic regulator, which derives its information as to conditions in the cable from the change in resistance of a metallic circuit. The regulator is essentially an automatic Wheatstone bridge whose rebalancing mechanism controls also the telephone repeaters.

In applying the regulating system the cable is divided into sections usually from one to two hundred miles in length. Generally, all circuits passing through each section are automatically compensated by one "master regulator" placed at a repeater station near the center of the section.

Two cable-pairs, extending in opposite directions, are short-circuited at their distant ends, and resistances are connected in series with the shorter pair. Thus approximately equalized, the pairs are connected in parallel to form one arm of the bridge.

When the temperature, and conse-

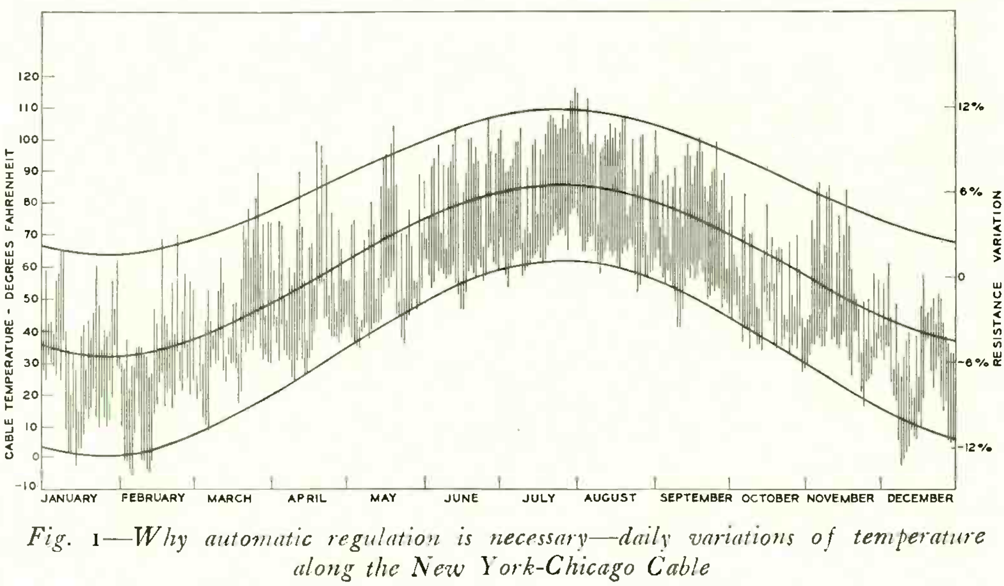

Fig. 1—Why automatic regulation is necessary—daily variations of temperature along the New York-Chicago Cable

quently the resistance, of the pilot wire changes, the Wheatstone bridge is thrown out of balance, and the galvanometer deflects. This galvanometer is part of a Leeds and Northrup motor-driven recorder. At intervals of a few seconds the driving

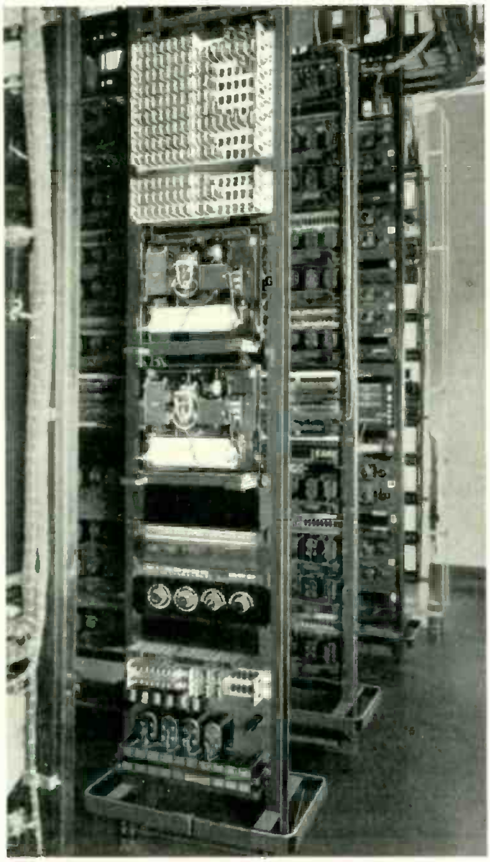

Fig. 2 — A regulator panel installed at Allentown on the New York-Chicago cable. At the top are the relays; next the "spare" and the "regular" regulator; then the lamps which indicate the regulator position; control keys; test jacks, dial-switches, and miscellaneous apparatus

motor, through a cross-bar, lifts the pointer of the galvanometer so that, if deflected, the pointer in turn raises one or the other of two levers. If not deflected, that is, when the bridge is in balance, the pointer passes between the ends of the two levers. Through an ingenious mechanical system, the raising of either lever causes a shaft to be rotated through a small angle, whose amount depends on the galvanometer deflection and whose direction depends on which lever is raised. The shaft in turn operates a slide-wire resistance to restore the balance of the bridge, and also moves the arm of a dial switch over a series of contact-points connected to a group of relays, which in turn readjust the gain of the associated repeaters. In the case of 19 gauge H-174* circuits where the changes in transmission are substantially the same at different frequencies throughout the voice range, simple resistance potentiometers can be used to regulate the gains of the repeaters. In the case of 19 gauge H-44-25** circuits, however, difficulty was encountered in the fact that changes in transmission at low frequencies produced by a given resistance change are less than those at high frequencies. More complicated networks were therefore required to vary the gain differently at different frequencies.

There are ten steps on each side of the "zero" position of the dial switch; that one which is in contact with the arm is indicated by a lighted lamp on the control panel. The central "zero" step is symbolized by a green lamp; the extremities by red lamps and the remaining steps by white lamps. Should the regulator stop with the arm bridging two contacts, the relays change the gain by one-half the amount of a full step. A permanent record is made by a pen travelling

* *Sometimes called "medium heavy loaded."*
** *Sometimes called "extra light loaded."*

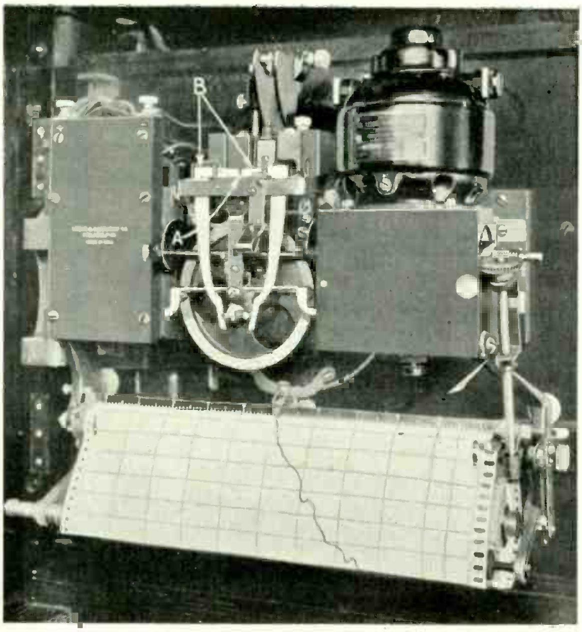

Fig. 3—A close-up of the Leeds and Northrup recorder which is the heart of the system

across a chart which in turn is advanced by the motor at one and one-half inches an hour.

Trouble on the pilot wire, such as an open or short circuit, looks to the regulator like a sudden large change in the attenuation of the cable. Doing its best to meet the emergency, the regulator would change the repeater gains quickly through a considerable range, perhaps even to the limit of its ability, with disastrous results on telephone transmission. By an ingenious mechanical modification of the mechanism, the galvanometer is prevented from operating the bridge in case of a large deflection, but instead intermittently lights a lamp and sounds an alarm buzzer. Still greater unbalance of the bridge might send so much current through the galvanometer as to endanger its winding. A relay with differential windings in two of the bridge arms is therefore provided; its operation short-circuits the galvanometer and operates the lamp and buzzer signals continuously. In both these cases, disappearance of the trouble restores the apparatus to its normal operation.

Under extreme conditions of temperature, or for other reasons, the resistance of the pilot wire may change beyond the ability of the regulator to follow it. On the tenth step of the dial switch, a contact is closed which stops the driving motor, disconnects the battery supply from the bridge and operates the buzzer. As soon as circuit readjustments have been made, the attendant sets the dial switch on the ninth step and places the apparatus again in operation. Should the trouble persist, the regulator would advance to the tenth step and the alarm would again be given.

Direct current at 110 to 130 volts is required for the bridge circuit from

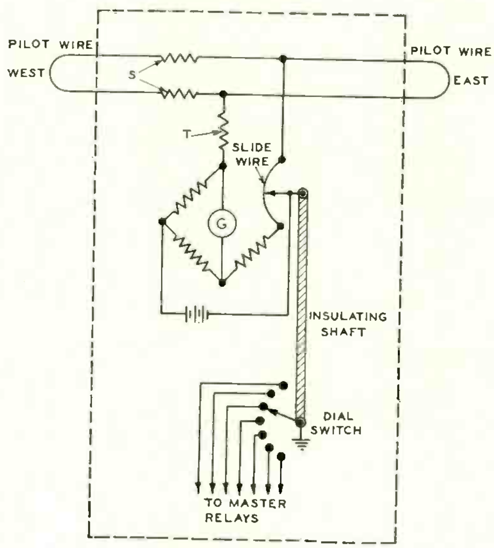

Fig. 4—The Wheatstone bridge circuit in simplified form

an ungrounded battery. Since the current drain is only about twenty-five milliamperes, either dry or storage cells may be used. Failure of this current-supply lights a lamp and operates the buzzer. Current for the motor is drawn from the 24-volt battery.

Ideally, the pilot-wire should be loaded in the same way as the telephone circuits which it is to control. The regulator has been designed for use with 19 gauge H-44-25 pilot wires, since these circuits require the most accurate regulation, and field trials have shown that other types of circuits are then controlled with sufficient accuracy. Non-loaded 19 gauge pairs may also be used. Spare pairs may be used as pilot wires, or a metallic (ungrounded) circuit may be obtained by use of two composited telegraph circuits connected at their distant end. To balance out the composite coils, whose temperature-change is that of central-office air, a number of resistances wound with copper wire are included in the regulator circuit.

Setting a transmission regulator in operation requires, beside the installation and mechanical test of the apparatus, some careful tests of the lines involved. The zero position of the slide-wire corresponds to an average temperature of the pilot wire of fifty-five degrees F. In general, the cable at the time of test will be at a different temperature, so the slide wire must be set at some other point. Knowing the theoretical resistance of the pilot wire at fifty-five degrees, and adding to this value the nominal resistance of the composite coils, if any, it is possible by comparison with the measured resistance of the cable to determine where the slide wire should be set at the time of installation.

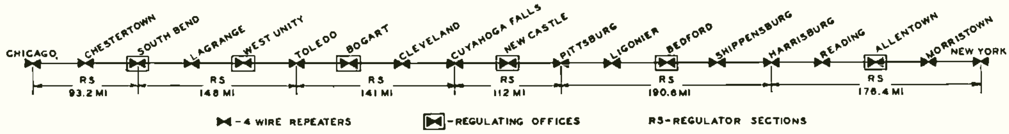

Fig. 5—How regulators and repeaters are spaced on the New York-Chicago Cable

The regulator motor having been started, the battery circuit is closed. If necessary, the bridge is balanced by adjusting resistances *T* and *S*. Finally, transmission measurements with 1000-cycle current are made on one or more of the 19 gauge H-44-25 circuits to be regulated. With individual repeaters adjusted to give their specified gains, the overall transmission equivalent of the circuit must be that specified to within 0.2 db; otherwise the resistances *T* and *S* are varied to secure the required agreement.

Regulators are installed along all long-distance cables; for example, between New York and Chicago there are regulators at Allentown, Bedford, New Castle, Bogart, West Unity and South Bend. In the area covered by the Long Lines cable plant, about 4 of these devices are constantly on guard to help maintain satisfactory telephone transmission.

Corrosion of Lead Cable Sheath

By R. M. BURNS
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CORROSION is a term used to describe the reaction of a metal to elements of its environment such as water, oxygen, carbon dioxide, gaseous sulfur compounds, acids, alkalies and salts. All metals corrode but in many cases the product of corrosion is a protective film which retards or prevents continuation of the action. A film is protective only if it is adherent to the metal, continuous, and insoluble in the surrounding medium. Films which are not continuous may modify or even accelerate the rate of corrosion.

Lead forms protective films under certain conditions. For instance when exposed to the atmosphere it tarnishes and becomes inert owing to the formation of an oxide film which increases in thickness during a period of about ten days. In the presence of moisture and carbon dioxide, lead becomes coated with a film of lead carbonate. While this film considerably reduces the rate of corrosion it does not prevent corrosion. The carbonate film forms when a small amount of carbon dioxide is present, and the rate of corrosion is then governed by the rate at which oxygen permeates or diffuses through the film. A third kind of film is formed on lead by small amounts of soluble silicates. The existence of this film on the surface of lead prevents its corrosion in slightly acid, neutral or slightly alkaline solutions. Under high conditions of alkalinity, however, this film dissolves and is no longer protective.

Corrosion, according to the modern viewpoint, is an electrolytic process. It depends upon the existence of small potential differences between different points on the metal surface, making tiny batteries, and upon the character of the reactions which occur at the electrodes as a result of the flow of small electrical currents. The fundamental reaction for the corrosion of lead may be represented by the equation:

$$\left.\begin{matrix}\text{Lead atom} + \\ \text{2 hydrogen ions}\end{matrix}\right\} = \left\{\begin{matrix}\text{Lead ion} + \\ \text{2 hydrogen atoms}\end{matrix}\right.$$

This is merely a statement of the fact that metallic lead dissolves at anodic areas and that hydrogen "plates out" as atoms on cathodic areas. There is formed in this way a film of atomic hydrogen which must be removed if corrosion is to proceed, the rate of corrosion being dependent upon the rate of removal. The process of hydrogen removal consists either in evolution as hydrogen gas or in oxidation. From a lead surface there is little tendency to evolve hydrogen even in highly acidic solutions. If however there are present other metals or substances such as copper, iron, carbon, etc. which more readily discharge hydrogen as a gas, corrosion is accelerated. More commonly hydrogen is removed from these cathodic areas by oxygen or oxidizing substances with the formation of water, and for this reason the rate of corrosion is determined generally by the rate at which oxygen reaches the lead surface undergoing corrosion.

Certain secondary reactions occurring at the electrodes often influence corrosion. For instance, the products of electrolysis may offer resistance to the flow of current or may by film formation on anode areas reduce or prevent dissolution of the metal. In the latter case current flow may continue, the anode process consisting of gas evolution (usually oxygen). On the other hand, electrolysis may result in the formation of a substance which is corrosive to the metal. For example, alkali and lime salts are converted into caustic alkali and free lime at the cathode and these attack lead.

A knowledge of the relationship of anode and cathode potentials to current density, make it possible to predict under given conditions whether or not a metal is likely to corrode. The influence of surrounding conditions may be illustrated by the behavior of lead in solutions of acetic acid, in which it dissolves readily, and in solutions of sulfuric acid, in which it is but slightly soluble. In the former case small potentials yield high current densities (corresponding to high rates of corrosion) while in the latter case relatively high potentials are required to maintain even moderate current densities. Moreover in this latter case formation of a lead sulfate film on the anode prevents corrosion at current densities corresponding to appreciable rates of corrosion.

The sheathing used for telephone cables consists of lead or more generally an alloy of lead and one per cent of antimony. While the alloy is somewhat more resistant to corrosion than is lead, the corrosion reactions in the two cases are similar and for the purposes of this paper may be considered as identical.

There are from a practical standpoint four kinds of corrosion to which cable sheath is subject. These are characterized as (1) soil or soil water, (2) acetic acid or white lead, (3) stray current anodic or ordinary electrolytic, and (4) stray current cathodic or negative corrosion. Fundamentally, these types of corrosion are all electrolytic and involve the same mechanism, the distinction between them having to do mainly with the source of potentials responsible for corrosion. In the first two classes the potentials are galvanic in type and arise from a lack of homogeneity either in the metal or in the medium adjacent to it; the third type, stray current anodic, is due to potentials picked up from improperly insulated power circuits, i.e., street railway, light and power lines; and the last class, stray current cathodic, is a combination of the galvanic and stray current types or in the ordinary sense a chemical reaction between the cable sheath and caustic alkali or free lime generated by electrolysis when the sheath is cathodic or negative to earth.

Whether a metal is corroded uniformly or pitted locally depends upon the area, position and number of anodes in a small area. If the anodes are large in area or numerous the attack tends to be uniform in appearance. This is illustrated in the corrosion of lead in acetic acid. If the anodes are widely separated or of small area with respect to the area of the lead surface, then the attack is of a pitting nature. In the case of cable sheath pitting action is the more dangerous since it produces perforaon of the sheath in a shorter time.

While soil corrosion is not a serious problem in cable maintenance, occasional cases are reported. It is due generally to exposure of different parts of the sheath to different concentrations of oxygen, salts, acids or alkalies. Pitting action initiated by stray current electrolysis may continue after elimination of the positive potential conditions owing to the fact that the pits, being less accessible to oxygen, become the anodes of galvanic cells which eventually cause perforation of the sheath. This is doubtless the explanation of many cases of "old action." Soil corrosion of cable sheath sometimes occurs in regions where there is an abrupt change in the character of the soil. This might have been predicted from laboratory studies which have shown potential differences of more than 0.3 volt between lead electrodes immersed in two different soil waters.

It is not uncommon for the sheathing of underground telephone cables to carry as much as 100 amperes of current derived from leaky power circuits. Under these conditions, on a full size cable there is an IR drop along the cable of about 0.1 volt per hundred feet which may create a large-scale galvanic cell provided there is a low-resistance path through the earth between two points on the cable at some distance apart. Precaution against corrosion in such a case consists in bonding the two points with a metallic conductor, thereby completing a metallic circuit and preventing current flowing from the sheath to earth.

The corrosion of cable sheath by acetic acid vapor occurs sometimes in creosoted wood conduit. It depends upon the maintenance of a suitably high concentration of hydrogen ions in the presence of oxygen and carbon dioxide and the formation of a non-protective film of basic lead carbonate. Early cases of cable sheath corrosion in creosoted wood ducts resulted from the use of wood creosote containing acetic acid. Recent extensive corrosion of this type on the Pacific Coast has been found to be due to the use of Douglas fir ducts incompletely creosoted. This wood is markedly more acidic than southern pine, which is used largely in other parts of the country for wood conduit, and moreover fir conduit is difficult to penetrate with creosote. The corrosive attack appears to have been stopped by neutralizing the acid with ammonia gas forced through the ducts in a mixture with air.

The most dangerous and most common kind of corrosion to which cables are subject is the ordinary electrolytic or stray current corrosion which may occur when the sheath becomes positive to earth. Here moisture conditions and soluble salts are of considerable importance since these affect the earth resistance and the anodic areas and hence influence the current densities at the point where current flows from the sheath to earth. Precautions against this type of corrosion consist in periodic electrolysis surveys, the bonding of cables to the negative returns of power circuits, and sometimes the shielding of the cable network against stray currents.

Finally there is cathodic or negative corrosion to which reference has already been made. This is characterized by the formation of red crystalline lead monoxide which crystallizes from saturated solutions of lime or alkali plumbites. Lead is readily dissolved by strong alkalies with the formation of plumbites which are stable only in solution. The alkalies responsible for corrosion may be produced by the electrolysis of soluble lime or alkali salts. Sodium chloride or ordinary table salt is used sometimes to thaw out street car switches in winter and occasionally finds its way into cable ducts where it is converted into caustic soda at the surface of the cable sheath as a result of current flow from the earth to the sheath. This type of corrosion also occurs in newly manufactured concrete conduits owing to the presence of free lime in the concrete.

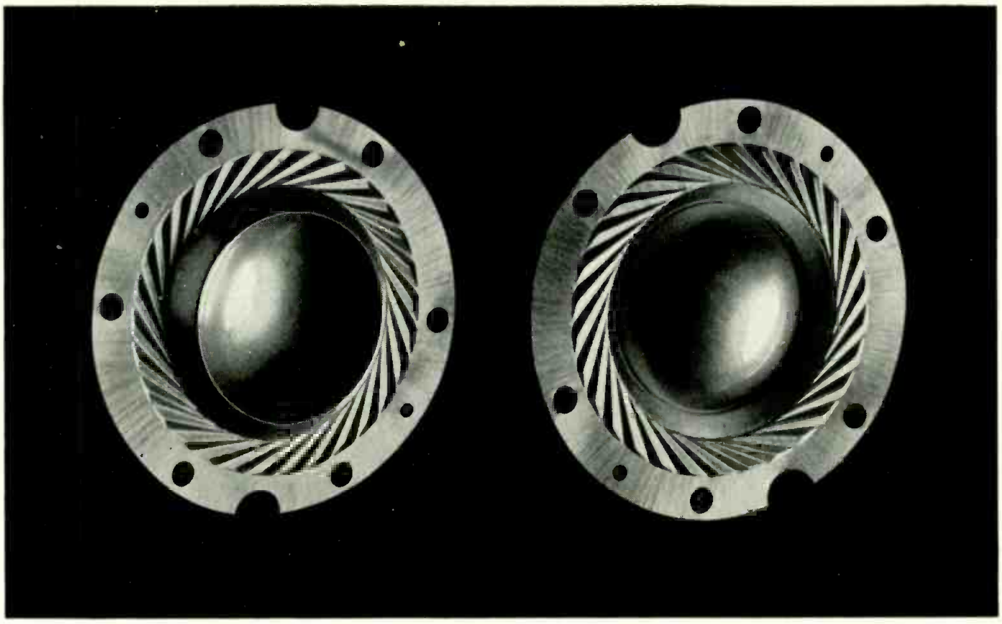
It might be inferred, from this summary of the mishaps which may befall a lead sheath, that underground cables are a rather vulnerable point in the Bell System plant. As a matter of fact, the losses of cable due to corrosion are relatively small, thanks largely to care in the selection of conduit material, and to the skill and vigilance of the Plant Departments' forces. But when it is recalled that the Bell System has in service some 55,000 miles of underground cable, containing nearly thirty-eight million miles of wire, it is evident that no pains are too great to find the causes and so prevent corrosion of the protecting lead sheath.

High-Strength Aluminum Alloys for Diaphragms

By W. J. FARMER
Apparatus Development Department

FOR the past ten years, aluminum alloys have to an increasing extent taken the place of steel, brass, bronze and other more common metals in many fields of industry. Used in the form of thin sheets, one group of the alloys has brought marked advantages to certain of the newer developments in telephone transmitters and receivers. There, used as diaphragms, they contribute prominently to high operating efficiency.

This group presents such a range of mechanical properties that those desired for almost any use can be secured by choice of an alloy of suitable composition, coupled with appropriate metallurgical treatment. Since strength, elongation and ductility can be controlled within wide limits, the necessary values in these respects can be secured in any cases but the most exacting. The greatest advantage, of course, is the low density, about a third that of steel. Another major advantage with most of the alloys, not otherwise found in nonferrous metals, is that parts can be increased in strength by heat treatment when they are in final manufactured form. Less important, manufacturing operations are facilitated by the low modulus of elasticity. It is about a third that of steel, so that the force needed for bending and other forming operations is about a third that which would be required

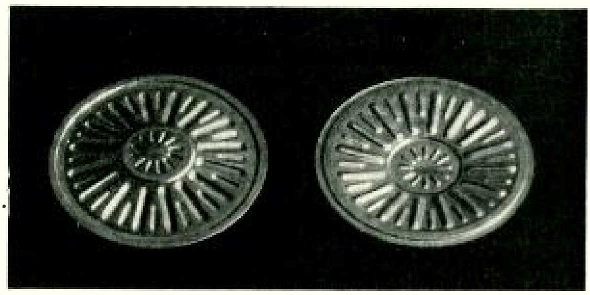


Formed diaphragm for a WE-555 Receiver, made of 17ST Alloy 0.002 inch thick. It is used principally with sound-picture apparatus

with steel parts of the same strength. The alloys are not immune to corrosion, but are much less subject to it than many of the materials which might be used in their stead. A quite different consideration makes them available for use in large quantity: the cost, although commonly considered high, is about the same as that of steel, when taken on the basis of volume rather than of weight. These facts, therefore, mean that there are available materials higher in ultimate tensile strength and in elastic limit than mild steel, with approximately one third the weight for a given part, and costing about the same per part.

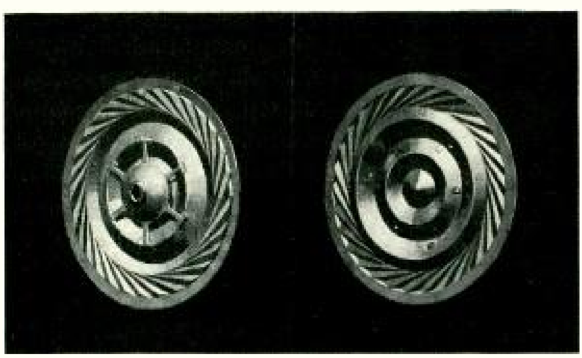
Many different compositions are available, but discussion will be confined to the two alloys commonly used in thin sheet form for diaphragms. These are the 17S or duralumin alloy and the 3S alloy. They are known by these numbers in accordance with the code adopted by the principal supplier, wherein each alloy is identified by a number followed by the letter S. That code reveals the chemical composition only; the temper and metallurgical treatment are given by a supplementary code consisting of one or more letters. These symbols do not tell the complete history, but only the processes revealing the current condition. Annealing is represented by O, and cold-working by H. W represents heat-treating followed by quenching only, T those processes followed by aging, and RT the more common sequence of heat-treating and quenching followed successively by aging and cold-working. The material for a particular diaphragm may therefore be 17SO at one stage of manufacture, after it has been annealed to facilitate forming, and at the end, when it has been hardened for use, be 17ST.

Duralumin is made up of approximately 4% copper, 0.25% silicon, 0.5% each of manganese and magnesium, and the remainder commercially pure aluminum. Although the total percentage of alloying ingredients is small, this material, whose density is very little higher than that of pure aluminum, can be brought by means of a tempering process to a tensile strength of 55,000 pounds per square inch with a substantial degree of ductility. The tensile strength may be raised by subsequent cold-working to at least 70,000 pounds per square inch; at the same time the property of ductility is almost entirely lost. Tempering may may be produced in various ways, but the usual method consists of heating the material to approximately 510° C., quenching it in water and allowing it to age at room temperature. Heating at this temperature for seven to ten minutes is usually sufficient for thin stock. The hardening proceeds very rapidly at first and then at a gradually diminishing rate until the maximum is reached at the end of five days. After heating and quenching, hardening may be carried out more quickly by maintaining the parts at 100°C. for a period of forty hours, a process known as artificial aging. When a part is to be made from heat-treated duralumin, there must be no delay between heat-treating and forming else the material will become so hard that it may fail in the course of the forming operations.



Diaphragm of handset transmitter; the material is 17ST Alloy

For use in several pieces of apparatus it has been necessary to raise the ultimate tensile strength of the 17S alloy to 75,000 pounds per square inch, and in special cases to as much as 85,000-95,000 pounds. This was accomplished by reducing the cross-sectional area about 90% through operations known as cold-working — swaging, drawing, rolling, and other cold processes. Material so handled, characterized by high tensile strength and elastic limit and by very small elongation, is specified as 17SRT. For other operations, annealed material is reduced 80% in thickness by similar cold operations. The material thus produced, 17SH, has an ultimate tensile strength of 45,000 pounds per square inch and negligibly small elongation.



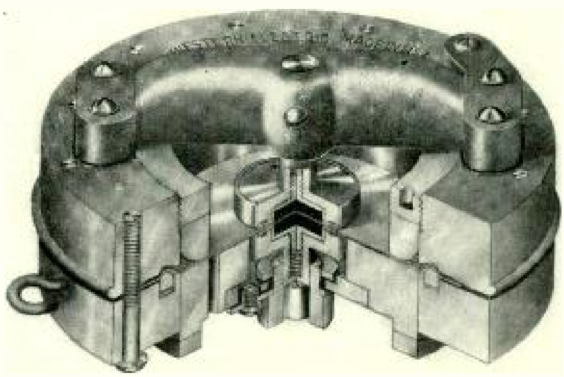
Reproducer for an Orthophonic talking machine, of 3SH Alloy; the spider is of hard commercially pure aluminum 0.014 *inch thick*

The other alloy extensively used, 3S, consists of commercially pure aluminum to which has been added approximately 1¼% manganese. In the annealed state it is about 25% stronger than annealed pure aluminum, and of slightly lower elongation. By cold-working its tensile strength may be brought up to about three times that of annealed aluminum, with a high ratio of elastic limit to ultimate strength. This alloy is therefore an extremely useful material in cases where severe forming is required. It does not, however, respond to heat treatment.

Both of these alloys may be rendered soft and ductile by annealing at approximately 343°C. at any time in the manufacture of parts if the hardness was caused by manufacturing operations carried out on formerly annealed material. Where the hardened condition was produced by heat treatment, as may be the case with duralumin, annealing requires heating for a longer time and at a higher temperature, followed by very slow cooling. Some of the deeply formed diaphragms are annealed a number of times in the course of production to remove the hardness resulting from the stresses of the forming operations.

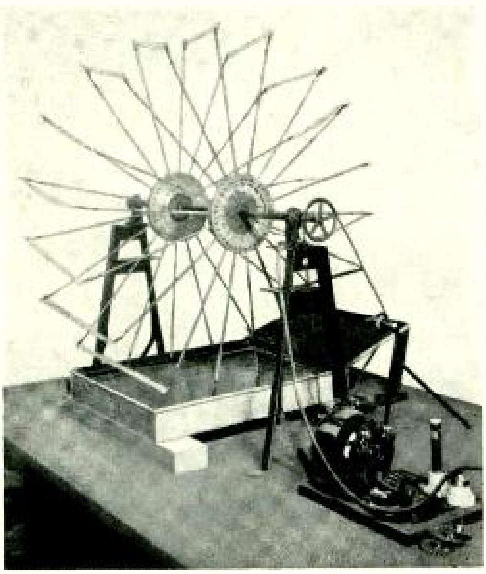
The alloys are received at the Hawthorne plant of the Western Electric company from the manufacturer in coils 0.020 inch thick. There they are rolled into ribbons of the thickness wanted, and generally just wide enough to make the blank for a single diaphragm. In all cases the material is buffed as it comes from the rolls. By this operation the resistance to corrosion is raised materially by the highly polished surface obtained. The thinnest material in use at present is a duralumin alloy for spacing washers of condenser transmitters; its thickness is only 0.00075 inch, about a sixth that of the paper on which the RECORD is printed. The most common thickness is 0.003 inch, and the thickest material commonly used is 0.005 inch.

Aluminum and its alloys are generally considered resistant to corrosion, and for thicknesses greater than 0.020 inch that is the case. In several pieces of apparatus the alloys are used in sheets 0.001 inch to 0.003 inch thick; obviously a very small degree of corrosion would be enough to reduce the cross-section of those parts by an extent sufficient to cause failure. Corrosion has therefore been studied intensively on pieces of apparatus and on the sheet stock as well. Since interest was mainly in objects 0.0017 inch and 0.003 inch thick, the tests were carried out on tensile samples cut from materials of these thicknesses. Several methods of corroding the alloys artificially have been



387-W Transmitter, for broadcasting. The diaphragm, which passes between the two carbon buttons, is a sheet of 17SRT Alloy, 0.0017 *inch thick, stretched by the clamping ring* tried, principally spraying with a salt solution, outdoor exposure tests on the roof and intermittent immersion in corroding solutions.

Our most dependable corrosion test makes use of a device resembling, on a small scale, the Ferris wheels of



Ferris wheel for corroding the aluminum alloys artificially

amusement parks. The device was developed by the Chemical Research Department. The tensile samples after measuring and cleaning are clamped into position at the circumference of the wheel, which is then rotated slowly and evenly for eighteen hours. They dip successively into the corroding solution at the bottom of each revolution and then drain and dry while completing the cycle; the corrosion occurs during drying. At the end of the corroding process the samples are removed and are broken in a tensile testing machine. Uncorroded samples from the same stock are also broken, for comparison. Protective finishes are appraised with the same piece of testing apparatus; coated and unprotected samples are exposed together, and then the ultimate tensile strengths of both groups are determined.

As rated by this machine chemically pure aluminum was highest in resistance to corrosion, and commercially pure aluminum second. Then followed a number of alloys, depending for their order on the treatment they had undergone as well as on their composition. The corrosion resistance is also determined in part by the surface. As might be expected, when it is smooth and highly polished it affords a considerably smaller opportunity for corrosion to start than does the somewhat rough gray surface commonly seen on aluminum cooking utensils.

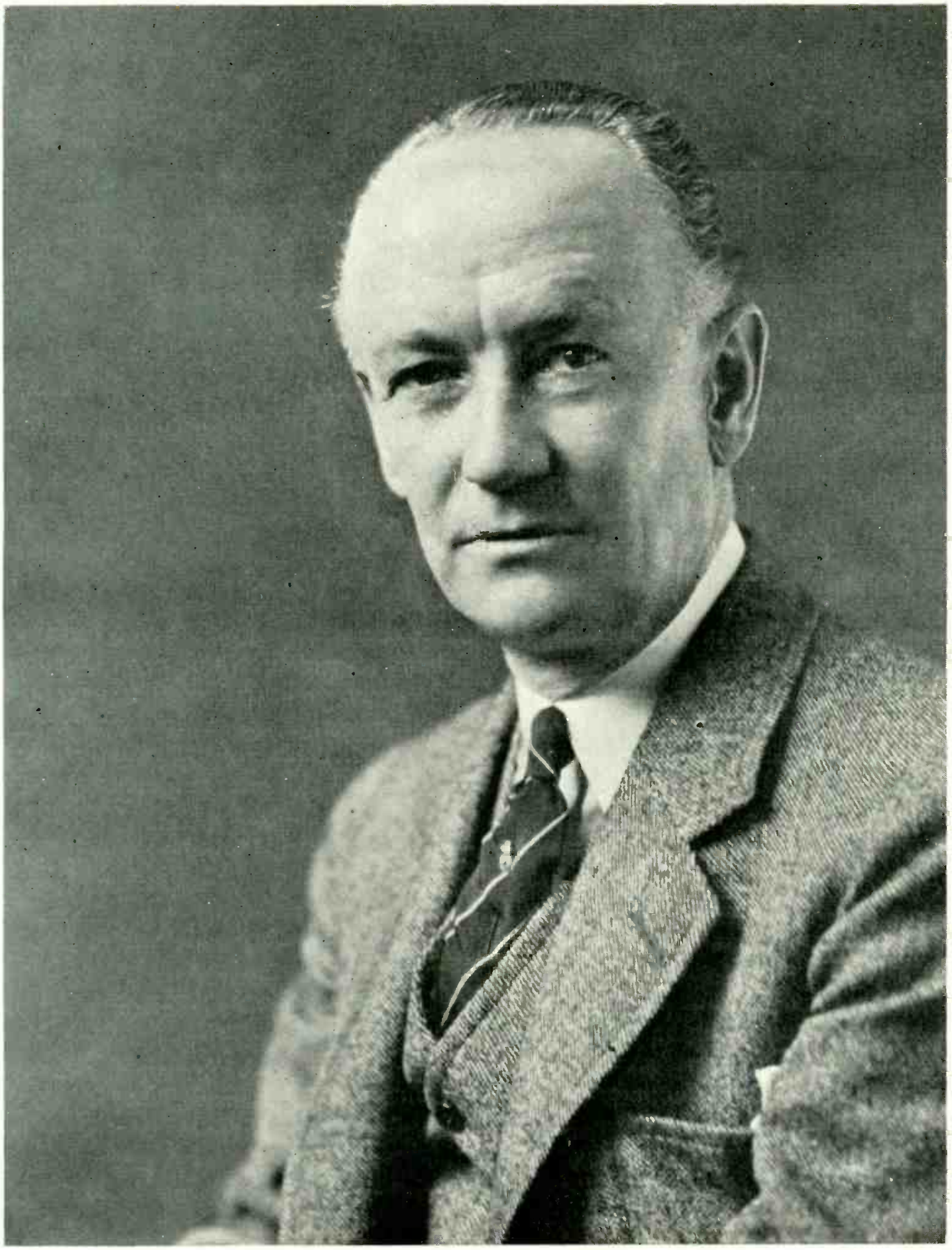
Choice of the alloy for a particular use cannot be made entirely on the basis of corrosion tests, of course; mechanical requirements at times are such that a particular alloy and temper must be used regardless of its low resistance to corrosion. For such cases the problem of increasing the resistance to corrosion, in order to insure that the part will last through the life of the apparatus, has been studied in the Chemical Laboratories. Either one or two coats of varnish, sprayed onto a finished part, affords satisfactory protection but adds appreciably to the weight. Thin Bakelite varnish is also satisfactory for alloys whose mechanical properties are not changed by the baking operation.

An interesting effort to combine moderate mechanical strength with maximum resistance to corrosion is the Alclad alloy, developed and manufactured by the Aluminum Company of America. Sheets are made by rolling a slab made of duralumin or one of the other alloys in the center and aluminum on the outside. Thicknesses of the layers are chosen to give a finished sheet of duralumin 0.002 inch thick covered on each side with 0.0005 inch of pure aluminum. Users can secure Alclad 3S, Alclad 17S, or sheets made with other alloys in the center, to suit their needs. Particular care is needed, however, in heat-treating Alclad sheets, since there is a tendency, while the material is hot, for the copper to diffuse from the center layer into the aluminum and so to reduce the corrosion resistance of the protective layers. The material presents interesting possibilities where there is danger of corrosion and where the necessity for lightness makes it inadvisable to increase the weight with a protective varnish.

Although aluminum and its alloys are used elsewhere in the telephone plant, these high strength alloys in sheet form find their most important use in the solution of a basic problem, the transfer of vibrations between the air and the vibrating member of a transmitter or receiver. For the most efficient and faithful transfer of energy the difference in impedance of the two media must be reduced to a minimum and for that end the moment of inertia of the diaphragm, and hence its mass, must be made as low as possible. In high-quality transmitters, where the flatness of the frequency-response curve comes in part from the fact that the range of resonance of the diaphragms is brought near the upper end of the voice frequencies by the tension under which the diaphragms are held, the material must be of minimum density, yet strong enough to withstand stretching to the desired tension. Likewise in the diaphragms of dynamic receivers stiffness is as much an essential as light weight, and strength is needed on account of the handling during assembly. For these uses, and for many others, the sheet alloys by their combination of high strength and light weight, and by their ability to withstand difficult manufacturing processes, make possible results that could otherwise not be attained.

The Edison Medal

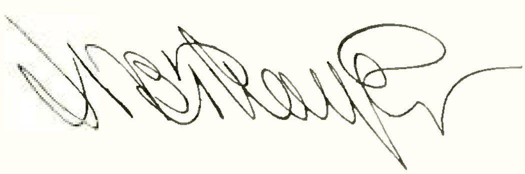
To Dr. Jewett has been awarded the Edison Medal for 1928, *in recognition of his "contributions to electrical communication". This medal is awarded annually by a committee of twenty-four members of the A. I. E. E., for "meritorious achievement in electrical science, electrical engineering, or the electrical arts". Among previous Edison Medallists are Alexander Graham Bell, John J. Carty and Michael I. Pupin.*



E. P. CLIFFORD, 1875-1928

WHEN I think of the decade in the history of the Western Electric Company beginning about 1895, I think of a period of intense and continuous activity. We were going through a revolution. We had been accustomed to growth but the kind of growth in which building factories becomes a routine was just beginning. We were finding that our methods in the shop and office had to be reconstructed to adjust them to the faster pace and that our organization had to be modified and expanded. But we had men.

Now, thirty years after, the specific difficulties do not linger in my mind. The picture I see is of a group of eager, resourceful, loyal, young men grappling the difficulties with the enthusiasm of a foot-ball squad going into the field. One of those young men, and not the least, was our friend Mr. Clifford. When you read the story of his progress in the Company, it does not mean stepping from one established, well organized position on to other better and similarly organized positions. It meant reconstructing a department and getting it to run smoothly and then repeating the process in a larger field. So, when during the war, the Laboratory found itself, almost over night, a commercial manufacturing concern, making in large quantities the apparatus needed by the Army and Navy, but without the necessary commercial and manufacturing organization or methods, it was Mr. Clifford who went into the Laboratory organization to supply what was lacking. There was no question then as to whether or not it was a promotion. There was his kind of a job to be done and he did it and he made it a promotion. We shall all remember him with great affection and respect. I shall also remember him as one of those who helped over the hard places.



Counteracting Dialing Errors in the Step-by-Step System

By T. L. DIMOND
Systems Development Department

IN dial systems it is necessary not only to provide means by which a subscriber may be connected with whatever party he is calling when he dials the correct number, but also to make arrangements for taking care of incorrect dialing as far as possible. Among the dialing errors which can be counteracted are those due to preliminary pulses, those which route calls to vacant selector levels, and those which direct calls to lines unequipped or out of service. These will be considered in the order named.

Occasionally it happens that a subscriber unintentionally sends what is known in dial parlance as a preliminary pulse before he dials the number of the subscriber whom he wishes to call. This preliminary pulse is generally caused by an accidental jiggling of the switchhook before the number is dialed. When the switchhook is momentarily pushed down after having been released, it opens and then short-circuits the two wires of the line as though the digit 1 had been dialed. This causes the selector in the central office to take one vertical step and prepare the circuits for the next digit.

If nothing were done to retrieve this error, upon completion of dialing the subscriber would obtain a number beginning with 1 and completed by all the digits except the last of the number of the called subscriber. In an exchange area using four-digit numbers, for instance, if a subscriber should desire to call the number 9284 and in preparing to dial send a preliminary pulse, he would in effect dial the number 19284, and would obtain the number 1928. The digit 4 would produce no result, since the circuits are so arranged that extra digits are ineffective.

In order to show how a step-by-step dial office is arranged to take care of this condition, it will be of aid to review briefly the progress of a correctly dialed call through such an office. Figure 1 gives a schematic showing the manner in which the ordinary line finders, selectors, and connectors are arranged in a four-digit step-by-step office. When a calling subscriber takes the receiver from its hook, a line finder immediately steps vertically until it reaches the level on which the terminals of the calling subscriber's line appear, and then hunts across the level until these terminals are found. The first selector, which is permanently connected to the line finder, then sends back a tone to the subscriber as a signal for him to dial. In returning to normal on the first digit the dial opens and closes the line loop, causing the first selector to step vertically one step each time the line is opened. As a concrete example let it be assumed that the number 9284 is dialed. When the number 9 is dialed, the first selector takes nine vertical steps and then hunts across the ninth level for an idle trunk leading to a second selector. On the next digit, 2, the second selector takes two vertical steps and hunts across the second level for an idle trunk to a connector. This connector has been chosen by the first two digits as the one having the terminals of the called subscriber's line appearing among the terminals accessible to it. The calling subscriber next dials 8. The connector steps vertically just as does a selector, but since it is now required to seize the terminals of a particular line on the eighth level rather than to choose an idle trunk from a group, it does not hunt over this level. As the subscriber dials the last digit, 4, the connector takes four steps in a rotary direction, seizes the line, rings on it, and connects the two subscribers together when the called subscriber answers. It may be seen that if the subscriber had given a preliminary pulse, in effect dialing the digit 1, the call would have been routed to a connector which did not contain the terminals of the called subscriber's line.

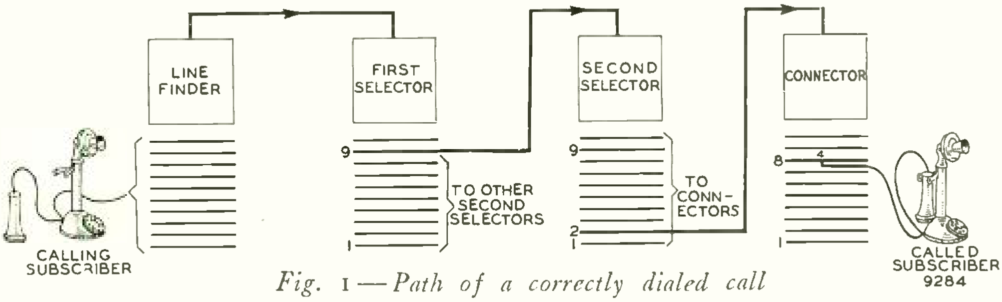


Fig. 1 — Path of a correctly dialed call

To prevent errors of this sort the arrangement shown in Figure 2 is used. The trunks from the first level of the first selectors, instead of being run to regular second selectors, are terminated in special second selectors which are in no way different from the regular second selectors insofar as circuit operation is concerned. However, the trunks from all levels of the special second selectors except the first are multipled to the trunks of corresponding levels of the first selectors. If the calling subscriber dials 9284 preceded by a preliminary pulse, or in other words dials 19284, the first selector will take one vertical step and find an idle trunk to a special second selector. When the digit 9 is dialed, the special second selector will step vertically nine levels and find an idle trunk. In effect, however, the ninth level of the special second selector is the same as the ninth level of the first selector because the trunks from these levels are multipled. Hence the call is now at the same point as it would have been if the preliminary pulse had been omitted. Further digits will direct it through the third selectors and the connectors to the same line as that to which the correctly dialed number would have routed it; the preliminary pulse has therefore been absorbed.

It will be noted that the employment of the first level of the first selector in caring for preliminary pulses prevents the assignment of subscribers' numbers beginning with the digit 1. However, it is desirable in any event to set apart one level of either the first or second selectors in a four digit office for calls to the information desk, the toll switchboard, the trouble clerk, and the reverting call selectors. In the interests of economy one level, the first of the selectors, is used both in counteracting preliminary pulses, and in routing the special calls just mentioned.

In order that the first level may also be used for the special calls, trunks from the first level of the special second selectors are carried to special third selectors, from whose levels, except the first, trunks go to jacks and other terminals for completing the calls. From the first level, trunks run to auxiliary third selectors, whose banks are multipled with those of the special third selectors to care for preliminary pulses on special calls. With this arrangement, subscribers are able to make toll, reverting and other special calls by dialing the number 11 followed by another digit. It may be seen from Figure 2 that the only additional apparatus required by this method of counteracting preliminary pulses is a comparatively small number of special second and auxiliary third selectors. Selectors equivalent in function to the special third selectors would be needed for the special calls in any case, even if no effort were made to compensate for the preliminary pulses.

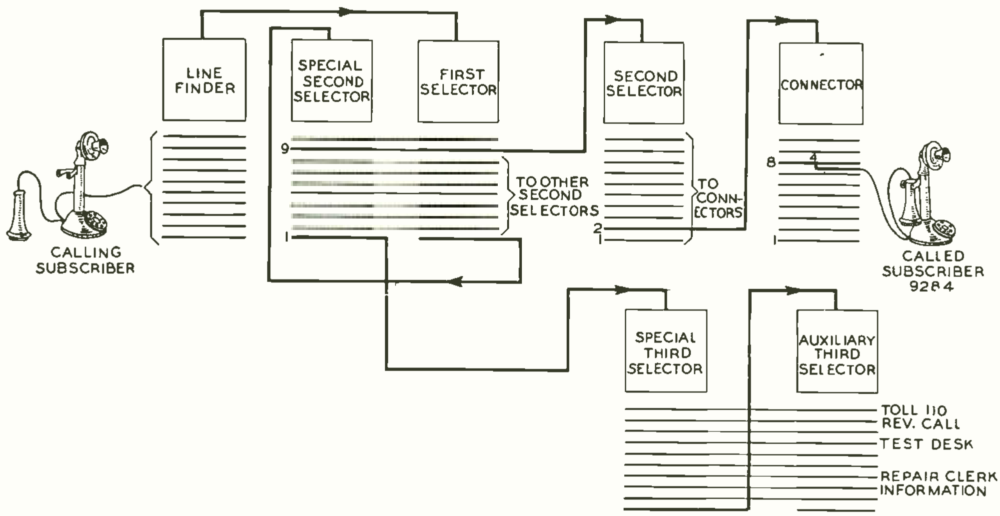


Fig. 2 — Path of a call preceded by a preliminary pulse, showing the supplementary switches for special conditions

The handling of service and other special calls may be seen by tracing calls with and without a preliminary pulse to the toll switchboard, to which the number 110 is usually assigned. Without the preliminary pulse the call will be directed from the line-finder to the first level of the first selectors, to the first level of the special second selectors, to the tenth level of the special third selectors, and thence to the toll operator. When preceded by a preliminary pulse, the call will advance from the line finder to the first level of the first selectors, to the first level of the special second selectors, to the first level of the special third selectors, and then to the tenth level of the auxiliary third selectors. Since this level is multipled to the tenth level of the special third selectors, calls routed to the tenth level of either group of selectors will go to the toll operator.

Having considered the method by which calls preceded by preliminary pulses are routed to their proper destination let us turn our attention to calls which are routed to vacant selector levels. The zero (tenth) level of the first selector is used for calls to the operator, and the first level is used as just described. Unless the central-office unit is fully equipped for the 8000 lines possible with the remaining levels no numbers will be assigned in certain of the hundreds and possibly in certain of the thousands, and the corresponding levels of the second or first selectors will be vacant. If a call were directed by the subscriber to one of these vacant levels, its progress would be immediately stopped, and, if no provision were made to care for such a condition, the subscriber would receive no indication to tell him what is wrong. Consequently two different methods of handling such calls have been developed, the method to be used for a particular selector level depending upon whether the calls which must be handled from this level are due to errors in the current directory or to subscribers' errors.

When there is a directory error involving a vacant selector level, all of the trunks of the level are made artificially busy except those which are carried through intercepting trunk circuits to jacks in front of an operator. If a selector starts hunting over a vacant level equipped in this manner, it will hunt over the busy trunks and seize one of the idle intercepting trunks, causing a lamp associated with the jack to light in front of the operator. The operator answers the call, inquires the number dialed and gives the calling subscriber the correct number.

Unless a directory error is involved, the calls which come to a vacant selector level are nearly always chargeable to subscribers' errors in dialing. Such levels have all trunks made busy except those which are connected to tone trunk circuits which, when seized by a selector, return a modified busy tone to the subscriber. The modified busy tone is the same as the ordinary tone, except that every third spurt is omitted. Since the subscriber has instructions that such a tone is received only because an incorrect number has been dialed, he has been informed that he has made some error and may act accordingly.

With either of these methods, the necessary number of intercepting trunk circuits or tone trunks is reduced by multipling the trunks from the several selector levels to the same intercepting trunk or tone trunk. When any one of the trunks becomes busy, it will cause all of the other trunks in the same multiple to test busy. Hence the number of selector level trunks which may be connected to the same intercepting or tone trunk is limited by traffic conditions.

Calls to unequipped or out-of-service lines are taken care of by a method similar to that used in caring for calls to selector levels involved in directory errors. Such calls may not in all cases be made on account of errors in dialing. For instance, the number of a subscriber may have been changed between the periods of directory changes. He is, of course, entitled to receive calls directed to his number as published in the telephone directory. Likewise a subscriber calling a published number can reasonably expect to have the call transferred to a more recent number, or to be informed of any condition preventing completion of the call. Accordingly, the terminals of lines involved in number changes, discontinuation of service and similar circumstances are carried from the connector multiple to trunk circuits which terminate in jacks in front of an operator. When a call is directed by a subscriber's dial to a set of terminals equipped in this way, a lamp associated with the trunk jack is lighted in front of the operator, who intercepts the call, inquires the number wanted, and explains the condition of the called line.

The number of trunks required from the unequipped connector terminals is reduced by multipling several connector terminals to the same trunk. Here again, the number which may be multipled to the same trunk is limited by traffic conditions.

H. D. Arnold's Remarks upon Receiving The John Scott Medal

I thank you for this award; and I wish to express my appreciation of the honor which it conveys. It is interesting to recall that it was here, in the City of Philadelphia, the vacuum tube mentioned in the citation found its first commercial telephone use. In September, 1913 vacuum tubes were installed here to relay conversations through the telephone cable between New York and Washington, and from that small beginning has come its present widespread use. In accepting this present recognition, Mr. Secretary, I feel doubly honored; I am proud to stand as the representative of that large body of scientists and engineers whose efforts have brought this development to its present state; and I am profoundly grateful to Fortune for allowing me to have a part in the early beginning of this important phase of telephone communication.

Operators' Transmitters and Receivers

By H. I. BEARDSLEY
Apparatus Development Department

WITH the institution of the first telephone central office there arose a need for transmitters and receivers which were suitably arranged for operators' use. The requirements for these instruments in central office service were so different from those of use at the homes and offices of subscribers that instruments for the two types of service necessarily were developed along separate lines. The development of operators' instruments has profited by the fundamental studies made upon instruments in general, but at the same time has involved differentiations in physical form to facilitate the work of the operators in handling subscribers' calls.

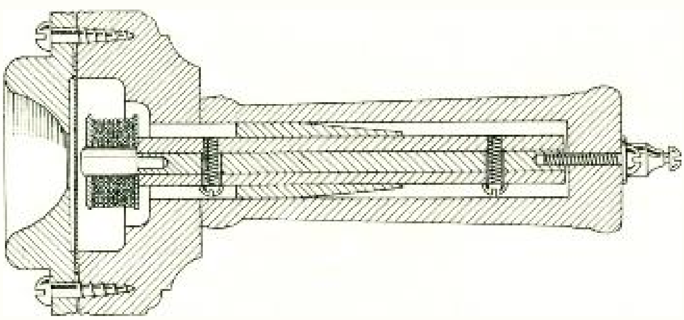
Succeeding the original "butter stamp" hand telephone the instrument, used by the operators in 1878, was a device serving both as a transmitter and receiver. In appearance slightly resembling a desk stand receiver of today, it is shown in use in Figure 1 of the historical pictures. Developed by Bell and known therefore as Bell's hand telephone, it was a single-pole, permanent magnet instrument. The magnet was a straight bar mounted at right angles to the diaphragm, and bore a coil placed around a soft-iron extension at the end. The earliest of these instruments were enclosed in cases of wood. When one was used as a transmitter, sound waves impinging upon the diaphragm caused it to vibrate and so varied the magnetic field, inducing in the coil varying currents which were electric counterparts of the sound waves. When this instrument was used as a receiver the incoming voice current, by its variations, changed the magnetic field of the coil through which it flowed, thereby vibrating the diaphragm and producing a close approximation to the original sounds.

The following year, 1879, there came the instrument shown in Figure 2. The transmitter and receiver units were separate, but were arranged to be held in one hand. The transmitter, of the type developed by Edison, was changed in function; it no longer generated the voice-current, but by changing its resistance in response to the sound waves it varied the current supplied by a battery. A toothed metal ring in contact with the back of the diaphragm pressed against the front electrode, a hard carbon disc. By that construction pressure of the disc against the back electrode, a disc of soft carbon, was varied, and the current was changed correspondingly. The receiver operated on the same principle as the older instrument and was made up of equivalent parts. Instead of being at right angles to the diaphragm however the bar magnet formed the handle on which the transmitter and receiver were mounted.

That same year there was introduced the operator's set of Figure 3, with the transmitter and receiver en-

1, *Bell's hand telephone in use as a transmitter. The same instrument acts as a receiver with incoming voice-currents;* 2, *Transmitter and receiver were mounted at opposite ends of a bar magnet in this operator's handset of* 1879; 3, *An early Blake transmitter and associated receiver, mounted to leave one of the operator's hands free;* 4, *Instruments the same as those of Figure* 3, *supported in a "Gilliland harness" to free both hands;* 5, *Another mounting arrangement keeping both hands free*

6, *A White Transmitter, and a Richards receiver mounted on a headband. The set was brought out in* 1891; 7, *Another supported transmitter, used with a completely enclosed receiver. Compactness of the receiver was obtained by use of a spiral magnet;* 8, *In this set the transmitter is essentially the same as those of today, and the receiver is of bipolar type, with a horseshoe magnet;* 9, *Today's set, with receiver held by a swivel yoke to a wire headband* tirely separate. The transmitter derived its name from Francis Blake, Jr., who carried out the original development on which it was based; its operation was by variation in resistance at the contact between the disc of hard carbon and a metal ball supported against the back of the diaphragm by a light spring. A heavier flat spring supporting the disc kept it pressed against the ball, so that vibrations of the diaphragm produced pressure differences at the contact area. To secure the proper range of pressures, adjustment was provided by supporting the spring upon a hinge-like member whose position was controlled by a screw. The transmitter was enclosed in a wooden box having an opening in front of the diaphragm, and was supported before the operator by a vertical rod. The receiver, held in the operator's hand during use, was unchanged in principle, but resembled in appearance the desk stand receivers with external binding-posts; the case was of hard rubber.



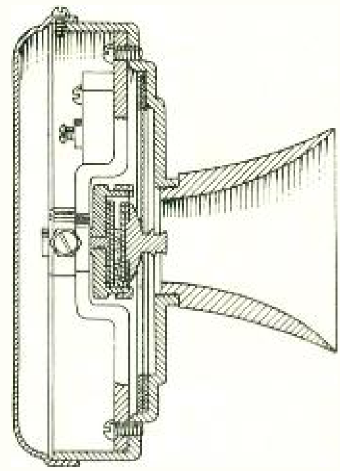
Section of Bell's hand telephone which was used as both transmitter and receiver

The next year the same instruments were mounted in a structure which freed both the operator's hands. This was the "Gilliland Harness" of Figure 4, an adjustable framework resting on her shoulders and strapped around her waist, supporting the transmitter a short distance in front of her mouth and the receiver at her ear. On account of its weight, almost 6½ pounds when fitted with instruments, this structure was not put into general use. Figure 5 shows another mounting arrangement brought out that year which held the transmitter at a convenient position by a vertical rod, and by a horizontal bracket held the receiver near the operator's ear. Though requiring that she hold her head in a particular position for speaking or listening, it was a noteworthy advance over the harness from the standpoint of comfort.

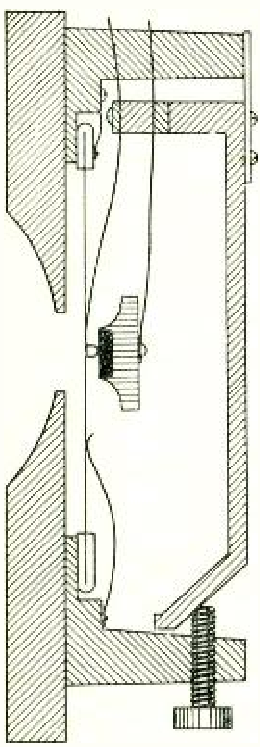
An important change in design was embodied in operator's transmitters produced in 1888. In accordance with a somewhat earlier development, both electrodes were of carbon and the space between was filled with carbon granules. Change in resistance with vibration of the diaphragm came from variations in pressure at the large number of contact surfaces between the granules, rather than at a single contact surface as before. In 1890 came the "solid back" design of Anthony C. White, not incorporated in operator's instruments however until the following year. The rear electrode was no longer mounted on a spring, but was attached rigidly through a small intermediate part to the back of the case, and the front electrode was held by a metal stud which passed through and clamped the center of the diaphragm. In 1891 a similar transmitter was made a part of the set shown in Figure 6. It is of interest to note that the mouthpece used resembles that of today's desk stands in size and shape.

The receiver used was designed in 1884 by W. L. Richards, now Consulting Historian of the Laboratories. It was one of the earliest of the thin or watch-case type, suitable for use with a headband. Essential parts corresponded to those of previous designs, but compactness was secured by placing the bar magnet on the outside of the receiver case to form the bracket by which the headband was attached. An extension, consisting of a soft-iron core at right angles to the end of the magnet, ran through the center of the coil inside the case. Small screws near the middle of the bar magnet fastened the receiver to a headband sufficiently large in area to distribute the weight well over the operator's head.

Another adaptation of an independently supported transmitter and



The carbon granules of the White solid back transmitter separating the two carbon discs, gave a large number of contact surfaces for variation in resistance



In Blake's transmitter a carbon disc was pressed by a flat spring against a contact point touching the diaphragm

headband receiver, that of Figure 7, was put into use about the same time. The transmitter was the same in internal structure as that just described, but was supported by a bracket extending from the switchboard. Though still of single-pole construction the receiver was made more compact by the use of a laminated, curved magnet of the so-called spiral type, enclosed within the case. Attachment to the headband was by a thumb nut.

About 1900 came the transmitter which is similar in form to that now used by operators throughout the Bell System. It was mounted on a breastplate supported and held in place by a tape extending around the operator's neck. Adjustment of the tape and movement of the mouthpiece in its ball and socket mounting bring the opening directly in front of the operator's mouth, and cleaning is facilitated by the ease with which the mouthpiece can be removed. The receiver used with this transmitter was of bipolar type, and a horseshoe magnet was substituted for the spiral magnet. Transmitter and receiver are shown in Figure 8.

The operator's set of today, shown in Figure 9, includes a transmitter similar in form to that just described but incorporating certain important changes, such as an improved carbon button, which make for better operation. A bipolar receiver with horseshoe magnet is used, but it is more efficient than the previous type, and its method of mounting is changed. On the outer periphery of the case are two small lugs, 180 degrees apart, with a hole in each for attachment of the headband. The band is made from a loop spring whose ends are clamped in a bracket; to the bracket is attached a swivel yoke with points for engaging the lugs. By the rotation and the free movement introduced, closer fitting is secured and extraneous noises are thereby excluded. These instruments, as is apparent, signalize a notable improvement over the early types of operators' sets, and embody the necessary electrical functions in a form which facilitates greatly the speedy completion of calls.

An Opener of Ways

Edward Preston Clifford, administrative officer of the Bell Telephone Laboratories, whose untimely death was recorded in Tuesday's newspapers, was not a scientific man. Yet the death of few New Yorkers could leave a wider gap in the human machinery of scientific research or one more difficult to fill. It was Mr. Clifford's lifework to help on other people's jobs; to hold an important place in the great army of those who smooth the pathway of science along which other men advance to more obvious renown. . . . For the notable accomplishments of his more strictly scientific colleagues Mr. Clifford and the skilled but unobtrusive administrators whom he had gathered deserve no small share of the praise.

—*From an editorial in the Herald-Tribune of December* 19, 1928

News Notes

Dr. Jewett was a member of the Advisory Board of The Second International Conference on Bituminous Coal held at Pittsburgh from November 19 to November 24, and presided over the morning session of the Conference on November 21. He was also a delegate to represent the National Academy of Sciences.

On November 23, Dr. Jewett attended the ceremonies at the inauguration of Harvey Nathaniel Davis as President of The Stevens Institute of Technology. On this occasion he also represented The University of Chicago, attending a dinner in honor of the delegates at the Hotel Astor on the evening of November 22.

Dr. Jewett gave a short talk before the Transmission Conference which met on November 16 at 195 Broadway.

At the December 3 meeting of the Colloquium, C. H. Prescott, Jr. spoke on "Chemical Equilibria at Incandescent Temperatures". R. V. L. Hartley spoke on "A Wave Mechanism of Quantum Phenomena" on December 17, prior to his presentation of a paper on that subject at the Christmas meeting of the American Physical Society.

There are now available for members of the Laboratories sets of personal financial records in booklet form. These records supplement the A. T. & T. income and expense record which has been available to members of the organization for some years. They are especially intended for those who do not keep a detailed expense account, but who wish to determine their financial status at intervals. Copies of these records may be obtained by applying to the Employee Service Department, Section 1-H, Extension 435.

Apparatus Development

H. Van Deusen, J. R. Townsend and C. H. Greenall were at Hawthorne during the week of November 19 in connection with the formulation of specifications for non-ferrous sheet and rod stock.

J. R. Townsend presented a paper on telephone apparatus springs before the Annual Meeting of the American Society of Mechanical Engineers in New York on December 6.

W. T. Pritchard visited "Marine" central office in Atlantic City to make studies of burnishing tools for step-by-step switches.

J. N. Reynolds was at Hawthorne during the week of November 12 in connection with new dial apparatus developments.

J. W. Beyer attended a meeting of the High Temperature and Electrical Resistance Alloys Committee of the American Society for Testing Materials at the Bureau of Standards in Washington.

F. F. Lucas spoke on "Microscopic Structure of Metallic Alloys" on December 28 before the American Association for the Advancement of Science at the Museum of Natural History, in this city.

E. W. Gent visited Hawthorne in connection with the production of a modulator unit to be used in equipment for a news reel camera.

R. NORDENSWAN was at Hawthorne in regard to the manufacture of a new loud speaker.

N. BISHOP recently supervised the conversion to provide crystal control and increased modulation in the five-kilowatt broadcasting equipment of the Churchill Evangelistic Association, now known as the Buffalo Broadcasting Corporation. He performed the same service for the Bankers Life Company of Des Moines; the Stromberg-Carlson Telephone Manufacturing Company of Rochester, and the one-kilowatt equipment of the Woodmen of the World at Omaha. He then inspected the five-kilowatt station of the National Life and Accident Insurance Company at Nashville, Tennessee.

B. R. COLE recently made a survey for Memphis Commercial Appeal, Incorporated, at Memphis, Tennessee, which recently purchased a one-kilowatt, crystal-controlled broadcasting equipment.

J. C. HERBER supervised the conversion to crystal control of the five-kilowatt equipments of the Moody Bible Institute and Sears, Roebuck and Company of Chicago, and the Consolidated Gas, Electric Light and Power Company of Baltimore; also the one-kilowatt equipments of Larus and Brother Company, Richmond, Virginia and the Detroit News and the Milwaukee Journal.

F. E. NIMMCKE supervised the conversion to crystal control of the one-kilowatt broadcasting equipments of the Universal Broadcasting Company of Philadelphia and the Peoples Pulpit Association at Rossville, Staten Island.

H. S. PRICE made surveys for the one-kilowatt equipment purchased by the Puget Sound Broadcasting Company, Seattle, and the five-kilowatt equipment purchased by the Southwestern Sales Corporation of Tulsa. En route he inspected the one-kilowatt station of Louis Wasmer, Inc. at Spokane, and visited Fort Worth to confer on the relocation of the one-kilowatt equipment taken over from the Searchlight Publishing Company by the Texas Air Transport Broadcasting Company.

W. L. TIERNEY has completed the installations of a one-kilowatt equipment for the Oregon State Agriculture College at Corvallis, Oregon, and a five-kilowatt equipment at Sherman Oaks, California, for the Western Broadcasting Company. He also made a survey for the five-kilowatt equipment purchased by Hale Brothers, San Francisco, and supervised the crystal control conversions of the one-kilowatt equipments of Don Lee, Incorporated, at Los Angeles and San Francisco, and of the Fisher Blend Station at Seattle, Warner Brothers at Los Angeles, and Nichols and Warinner at Long Beach, California.

O. W. TOWNER supervised the conversion to crystal control of the five-kilowatt equipment of the Voice of St. Louis, Inc., and the one-kilowatt equipment of the Jenny Wren Company, Lawrence, Kansas, the Gurney Seed Company of Yankton, South Dakota, and the Kansas City Star.

R. M. PEASE has, during the past few months, assisted S. P. Grace in demonstrations given in connection with Mr. Grace's talks. He was present at the latter's lectures before the Rotary Club of Brooklyn on December 6; Sigma Xi Chapter of McGill University at Montreal on December 19, and before the employees of The Bell Telephone Company of Canada at Montreal on December 20. He also aided in setting up the equipment used by John Mills in his Toronto lectures, December 13 and 14.

Systems Development

J. R. P. Goller and R. L. Lunsford inspected the new unit type toll repeater power installation at Greensboro, North Carolina. This installation is part of the Washington-Atlanta Cable.

J. R. Stone and C. Borgmann tested and inspected high speed centrifugal exhauster equipment for pneumatic tube installations in West Lynn, Massachusetts.

V. T. Callahan tested a BA gasoline engine set, recently installed in Savannah, Georgia.

C. E. Boman spent several days in Chicago in connection with problems of machine switching equipment.

I. W. Brown visited Milwaukee and Detroit, preliminary to the installation of new toll facilities there.

J. H. Sole visited the General Electric Company at Pittsfield, Massachusetts, to confer on the development of a transformer to provide current for lamp signals in toll boards.

J. Irish visited Chicago in connection with circuit drawings and practices.

D. M. Terry discussed the 1-A carrier pilot channel equipment with members of the staff at Hawthorne.

J. P. Kinzer visited Morristown, New Jersey, and Allentown, Reading and Harrisburg, Pennsylvania, in connection with modifications of 2-wire repeaters in cable circuits.

A. E. Bachelet conducted tests of half-ampere ballast lamps used with 2- and 4-wire repeaters at the A.T.&T. repeater station at Juliet, Illinois.

J. A. Krecek spent several weeks in El Paso, Texas, testing 2-wire echo suppressors to be used in conjunction with picture transmission circuits.

E. P. Bancroft is engaged in the installation of telephone and carrier telegraph equipment for the Canadian Pacific Railways.

C. B. Sutliff recently assisted with the demonstration of an oscillograph before the American Optical Society in Washington.

Research

J. M. Finch and A. C. Walker were present at a meeting of the American Society for Testing Materials at Philadelphia.

H. H. Lowry attended a meeting of the Committee on Insulation Materials of the National Research Council at Johns Hopkins University in Baltimore.

A. R. Kemp visited the plant of the General Electric Company at Bridgeport on November 20 to confer on the development of rubber covered wire and cable.

J. H. Ingmanson viewed a demonstration of the impregnation of jute for the protection of lead cable sheath, at the Schlichter Jute Cordage Company, Philadelphia.

W. A. Marrison demonstrated oscillographs of polar and motion-picture types at the apparatus exhibit held in connection with the meeting of the Optical Society of America in Washington.

C. H. Haynes conferred with representatives of the Standard Machine Company, Providence, on the construction of special rolls for the manufacture of platinum filament.

C. A. Kotterman made an inspection trip in connection with the Laboratories' exhibit at the National Academy of Sciences, Washington.

T. C. Fry spoke on the use of continued fractions in the design of electrical networks before the American

Mathematical Society in Cincinnati.

In "Science" for November 16, K. K. Darrow describes and correlates the results of recent experiments on the scattering of quanta with diminution of associated frequency. These phenomena are associated with the Raman effect.

J. M. Eglin described a direct current amplifier for measuring small currents before a meeting of the American Physical Society at Minneapolis on November 30.

C. J. Davisson and L. H. Germer presented a paper on a test of the state of polarization of reflected electron waves before the same Society on December 1.

J. C. Schelling addressed the Physics Seminar of Cornell University on November 19 on "Some Theoretical and Experimental Phases of Radio Transmission."

E. F. Kingsbury spoke on television before the Men's Club of Rutherford on December 14.

Inspection Engineering

E. G. D. Paterson visited the Highway Trailer Company at Edgerton, Wisconsin, on November 12, in connection with studies of inspection methods for automotive equipment.

W. A. Boyd attended a regular survey conference on step-by-step apparatus at Hawthorne.

H. F. Kortheuer and H. C. Cunningham attended a regular survey conference in connection with carrier equipment at Kearny.

G. D. Edwards visited Cleveland, Chicago and Boston during the latter part of November and early December, in connection with Field Inspection Engineering work. While in Boston Mr. Edwards attended the decennial anniversary celebration of the "Binaural Sons of the C", an organization composed of representatives of the United States Navy Department, the Submarine Signal Company, the General Electric Company, the Western Electric Company and of various educational institutions which cooperated during the World War in developing methods and apparatus for the detection and location of enemy submarines.

W. A. Shewhart visited Philadelphia during the latter part of October to attend conferences held by the American Society for Steel Treating and the American Society for Testing Materials.

Outside Plant Development

A. W. Dring investigated several special cable terminal installations in Philadelphia on November 13.

J. M. Hardesty made tests of reinforced concrete poles in Charlotte, North Carolina.

R. C. Eggleston investigated preservative treatments and made strength tests of jack-pine poles in Minneapolis, from October 20 to November 12.

E. M. Honan observed field trial installations of drop wire in the territories of the New York Telephone Company, the New Jersey Bell Telephone Company and The Southern New England Telephone Company.

General Staff

E. P. Clifford, Vice-President of the Laboratories, died Sunday, December 16. He entered the Western Electric Company in 1892 as an office boy, and became Cashier of the New York office some six years later. After experiences as Chief Clerk at Chicago, Philadelphia and New York, he became Assistant Manager of the New York House, and in 1911 its Manager, with supervision of the ton, Philadelphia and Pittsburgh Houses. In 1917 he was appointed Eastern District Manager of the Western Electric Company. On July 1, 1918, Mr. Clifford became Office Manager of the Engineering Department. A year later he became Commercial Manager and his responsibilities were gradually extended to embrace all non-technical activities. In 1925 the Engineering Department became Bell Telephone Laboratories, Incorporated, and Mr. Clifford, as Vice-President, was placed in charge of the General Staff Department.

G. B. THOMAS attended a dinner of electrical engineering students at Massachusetts Institute of Technology, at which the Bell System cooperative course was discussed. Mr. Thomas also addressed a group of senior students of electrical and mechanical engineering at Cornell University on December 14.

JOHN MILLS addressed the Central Association of Science and Mathematical Teachers at Chicago on December 1, on "Through Electrical Eyes." On December 13, Mr. Mills spoke before the Engineering students of Toronto University, and on the following day, before employees of The Bell Telephone Company of Canada in Toronto, on recent developments of these Laboratories.

S. P. GRACE included in his lecture program for December talks before the Rotary Club of Brooklyn, on December 6; Sigma Xi Chapter of McGill University, Montreal, on December 19, and employees of The Bell Telephone Company of Canada, Montreal, on December twentieth.

R. A. DELLER spoke on television before a group of Student Engineers at the New York Telephone Company Headquarters. "Through Electrical Eyes" was the subject of a talk given by him on December 4 before the A. S. M. E., A. I. E. E. and the Providence Engineering Society at Brown University.

EDWARD AIKEN, a porter in the Plant and Shops Department, died on November 17. He had been with the Laboratories since March, 1927.

L. S. O'ROARK spoke on the electrical transmission of personality before the Buffalo Section of the A. I. E. E. on December 14.

W. F. JOHNSON AND B. B. WEBB were in Trenton, Lawrenceville and Princeton, New Jersey, in connection with commercial matters involved in the installation of four short wave radio transmitters which the Laboratories are manufacturing for the Long Lines Department, American Telephone and Telegraph Company.

P. MAY has been assigned to duties at the Radio Station at Lawrenceville where he will handle the commercial phases incident to the installation of the short wave transmitting sets.

H. W. DIPPEL recently visited the Corning Glass Works, Corning, New York, to arrange for the purchase of glass needed for the enlarged tube shop program.

PATENT

W. B. WELLS visited Schenectady, and J. W. Schmied and P. C. Smith went to Washington, in connection with the prosecution of patents.

Club Notes

The next dance of the Club will take place on Wednesday, February 6, 1929. The music will be Herbert Hood's, and D. R. McCormack is arranging something very special by way of surprise. Tickets are $1.00, and are obtainable from D. D. Haggerty or the departmental representatives.

Urged by importunate Brooklynites, the dance will be held at the Hotel St. George. Contrary to the stubborn preconceptions of out-of-towners, Brooklyn Heights is quite as accessible for the average Club member as Manhattan. The I. R. T. thoughtfully built the Clark Street Station in a sub-cellar of the St. George — a fact to be remembered by Jerseyites, who will find that the trip from Cortlandt Street to Clark Street is a matter of only fifteen minutes.

Bowling

During the first half of the present season the amazing record of one hundred per cent attendance was established. One hundred and sixty men have bowled every Friday evening for fourteen weeks, and four additional alleys have been reserved for those who are not members of the regular league. These men, though not eligible for league prizes, will substitute in the order of their averages, for possible absentees of the league teams.

Club records show a decided improvement over last year's scores. There is keen competition for the various prizes to be awarded. Special interest is shown in the D. D. Haggerty Trophy, which goes to the bowler rolling the highest score for the entire season.

On November 23, the league officers expressed the season's greetings by donating two turkeys, to be awarded as prizes for the evening's highest scores. T. C. Rice and N. Scribner, each, to borrow a phrase from another sport, "got a birdie".

Hiking

The final event of the hiking season, on Sunday, November 25, narrowly escaped the blight of superstition. Of thirteen who entrained for Tuxedo only twelve were in evidence at Tuxedo station. But the satisfaction of those who had advocated drawing lots to decide which member of the party should be thrown overboard was short-lived. The thirteenth hiker, after buying a bar of chocolate to round out his luncheon, rejoin the group and the hikers gaily hit the trail for Mt. Ivy.

Snow had not yet fallen in the city, and the party was unprepared to find it underfoot (as much as one-quarter inch of it, in spots). No casualties resulted from this cause, however; the one snowball thrown, missed.

By way of the T-MI (Tuxedo-Mt. Ivy) trail and voluntary detours, the hikers wound their way through the Ramapo hills to Ladentown. Since the party was still full of vigor, though the scheduled hike had been practically completed, plans were revised, and the hikers swung down the road to Suffern. Such energy was bound to be rewarded, and it was, when the party came upon a cider mill and stopped to sample its product. Much refreshed, the group stepped out with a will and reached Suffern not merely in time for the train, but with ample leisure for a sumptuous repast in a nearby lunch wagon. And so to home!

Though the official hiking season is over, the committee is always glad to get in touch with Club members who are interested in that form of recreation. If you have not already made yourself known to them, call Miss Barton, extension 857, or Alexander Grendon, extension 637, and make sure to be informed of the hiking Club's further activities.

Basketball

The Laboratories team is tied for first place in the Bell System League, in spite of a handicap incurred at the start, when it lost its first game to the Installation Department of Western Electric. A number of ardent rooters have been witnessing the games, and Manager Granville Matthews is confident that our team will repeat the splendid showing it made last year. On Monday and Friday evenings, games are played at Stuyvesant High School; on Wednesday evening, at Erasmus Hall High School. The games begin at 8:30, and are followed by dancing.

The squad: Gittenberger, C. W. Maurer, Steinmetz, Christ, Cahill, Kirsch, Keogh and West.

Indoor Golf Tournament

First prize in the December indoor golf tournament was won by J. G. Dusheck, who defeated R. J. Nossaman two up. As a result, Mr. Dusheck, who obviously needs it least, has a season membership in the Indoor Golf Course of America.

With memories of Christmas window-displays, the entrants rather expected to see a toy elephant in the bushes of the thirteenth hole, or to hear the rattle of an electric train among the green valleys of the course. So realistic was the scenery that players were seen trying to open the swinging door of a supposed locker room.

Seventy-two entrants played twice around and G. A. Brodley won the medal offered for low medal score. The sixty-four who qualified were divided into two groups of four flights each. Group 1, Flight A was won by R. J. Nossaman, who early established a lead over N. Thorne, and finished at the Fifteenth, four up. Other winners in this group were R. Koernig, I. W. Whiteside, and J. A. Hall. J. G. Dusheck took the final match of Group 2, Class A from T. C. Rice by six holes. Scoring six "holes in one," and his usual coolheaded putting contributed to this victory. E. H. Clark, J. M. Heywood, and E. K. Ebehardt were the other winners of this group. Each winner in the two groups received a prize and the respective winners of Class A played off for the special prizes donated by the management. In this contest, Dusheck took the lead on the third hole. Nossaman came up even, but lost his lead at the ninth. He was two down at the sixteenth, and by a twenty-inch putt lost the seventeenth hole and the match.

The next indoor tournament will be held on January 30 on the same course.

Club Elections

Those elected as Club officers for the coming year are: O. M. Glunt, president; H. F. Dodge, first vice-president; Marian Kane, second vice-president; A. C. Thoesen, Tube Shop representative; J. W. Hultquist, Research; P. B. Fairlamb, Systems Development; and J. C. Kennelty, Commercial.

WOMEN'S INTERESTS

Swimming

Two swimming classes will again be conducted: one on Mondays from 7:00 to 7:30, starting January 7; the other on Wednesdays, from 5:30 to 6:00, commencing on January 9. The courses will consist of eight lessons covering a period of ten weeks at a charge of $2.50. They will be given at the Carroll Club, Madison Avenue and 30th Street, under the tutelage of Miss K. Spranger.

Basketball

The Bell System Basketball League, which this year has included the girls' teams, has provided a definite schedule of games. Two have been completed, with three more to be played on the evenings of January 7 at St. Luke's court, and January 16 and 30 at Erasmus Hall High School. Games commence at 7:30 and dancing follows.

The Laboratories team played two games outside its regular schedule, winning on each occasion. The first engagement was with the Federal Reserve team; the other, an exhibition game with the Long Island Division of the New York Telephone Company. Further outside games are to be booked. On our squad are Ann Barioni, Marie Boman, Marianne Grimm, Lilliam Kaempffe, Dorothy Murtha, Marie O'Neill and Natalie Skinner.

Bowling

Four women's teams have been bowling regularly every Friday since October 19, 1928 at Dwyer's. Though the women's bowling club is a new departure, it has become an unusually popular activity. Novices desiring an opportunity to play may arrange through Marion ane or Leona Feil to act as substitutes for members of the regular teams. Prizes will be awarded at the close of the season.

Christmas Poster Contest

After careful consideration, the committee in charge of the Christmas Poster Contest selected fifteen of the best posters, submitting these for final judging to two well-known commercial artists. The winning poster was reproduced and displayed on the bulletin boards during the Christmas season. It was made by E. Alisch, of the Equipment Drafting group who was awarded a prize of a ten-dollar gold piece.