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Are Electrons Waves?

By C. J. DAVISSON

An intimate discussion of the conclusions which must be drawn from the series of researches in electronic physics carried out by the author and L. H. Germer. Their results, of great and even revolutionary importance in the theories of modern physics, are being communicated to the scientific world by papers in its technical press.

SIXTEEN or seventeen years ago Professor W. H. Bragg wrote a lengthy article in which he showed how all of the then-known properties of X-rays might be reasonably explained on the hypothesis that such rays are streams of swiftly-moving neutral doublets endowed with appropriate properties to produce the various X-ray effects.

About a year later the whole of this carefully elaborated theory was nullified by a simple experiment which can be repeated in any X-ray laboratory in 30 minutes. Laue, Friedrich and Knipping in Germany had sent a beam of X-rays through a thin crystal of zincblende onto a photographic plate and had found the plate blackened not only in the path of the beam, but also in a number of other spots. These additional spots formed a symmetrical pattern about the strong central spot due to the directly transmitted beam. This simple experiment disposed of Bragg's theory because the pattern could be completely accounted for on the supposition that X-rays were waves, and could not be explained on the supposition that they were discrete particles.

The observed phenomenon was one of diffraction similar to that observed when one views a bright distant light through a tightly stretched handkerchief. Instead of a single point of light one sees a bright central point surrounded by a rectangular array of subsidiary points which depends for its structure and dimensions upon the geometry of the mesh through which the light is viewed, and upon the wave-lengths of the particular light in question.

When X-rays pass through a crystal, much the same type of phenomenon occurs. The atoms of the crystal function in a way similar to that of the apertures in the mesh and so-called diffraction beams issue from the crystal in directions which are determined by the wavelength of the X-rays and by the arrangement of the atoms in the crystal. The X-ray phenomenon is somewhat more complicated, however, because the scattering centers occur in three dimensions instead of in a plane. In both cases the observed effects are credited to the interference of waves scattered from regularly arranged centers.

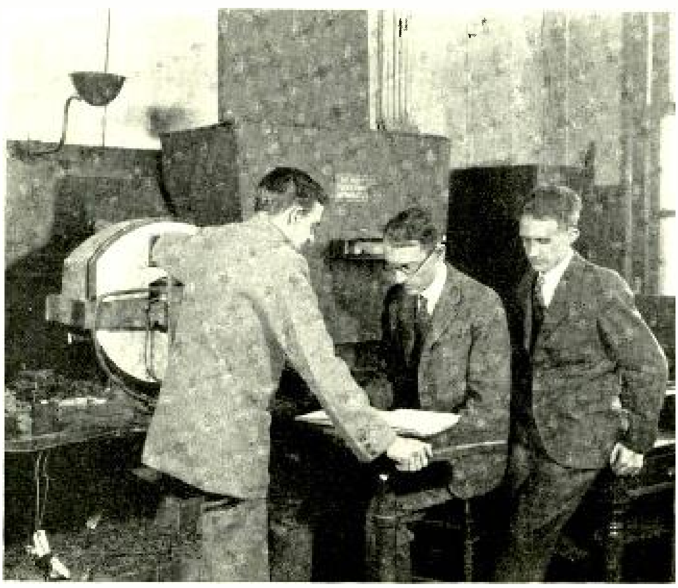
This experiment not only established the wave nature of X-radiation but also provided, on the one hand, a means of measuring X-ray wavelengths, and on the other hand, a means of studying the arrangement of atoms in crystals.

It is an interesting commentary on the spirit of science that no one accepted the implication of X-ray-crystal phenomena more readily than Professor Bragg and no one has done more to bring the technique of X-ray crystal measurements to its present high state of development.

The original experiment may be performed in a different way by interposing a photographic film between the source of the X-ray beam and the crystal. With this arrangement the same type of phenomenon is observed; the incident beam passing through the film produces a dense central spot, and about it a pattern of subsidiary spots is produced by the diffraction beams which issue from the illuminated side of the crystal.

Such in simple terms are the phenomena of the diffraction of X-rays and the generally accepted proof that X-radiation is a radiation of waves rather than of particles.

From these phenomena of X-rays we turn now to those of electrons. For years physicists have thought of the electron as a particle and have known many details concerning its electrical charge, its mass, its behavior under a variety of circumstances, and even something of its invisible size and shape. The tortuous track it leaves in traversing a gas has been observed. In the course of a series of experiments in our Laboratories, however, phenomena have been discovered which require a singular modification of these ideas.



C. J. Davisson, L. H. Germer and C. J. Calbick with the apparatus described in this article

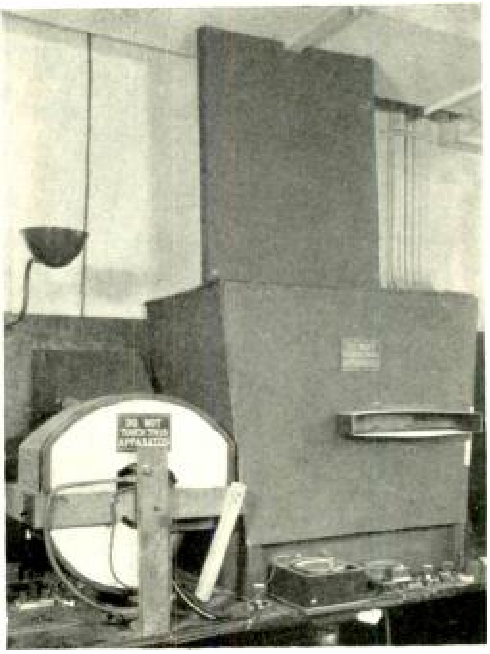
An experiment was performed in which a stream of electrons was sent against one face of a crystal of nickel and those electrons which then issue from the crystal observed by their effects. The experiment is exactly the same in principle and general method as the crucial experiment whereby Laue, Friedrich and Knipping determined the wave character of X-radiation. And the startling result is that when a beam of electrons is sent against a nickel crystal its electrons issue from the crystal in sharply defined beams which are disposed about the incident beam in a similar symmetrical manner. In other words, the essential features of the experiment with X-rays can be duplicated with a beam of electrons.*

What are we now to conclude? Does this mean that the electrons are waves? Well, very likely it does. For the experiment by which X-rays are judged to be waves can be duplicated with electrons even to the measurement of wave lengths.

A few years ago the situation would, indeed, have seemed inexplicable. For more than two years, however, the most advanced theorists in physics have been playing with the idea that electrons are in some sense waves. The idea originated with Einstein and L. de Broglie and has been, and is being, enthusiastically developed by Schrödinger, Born, Jordan, Dirac and others because of the escape it seems to offer from difficulties which exist in the interpretation of spectroscopic data in terms of the Bohr-type of atom model.

It is of course permissible to ask in what sense it is that electrons may be regarded as waves, since it is by no means obvious that there is any sense in which this is possible. It is customary in attempting to give a brief answer to this question—or, perhaps, more properly in attempting to establish a viewpoint in regard to it—to cite an analogy which is conceived to exist between the theory of optics and that of mechanics.

In solving certain problems in optics we sometimes make use of what



Apparatus for observing reaction between a beam of electrons and a single crystal of nickel

is known as Huyghens' construction; little wavelets are imagined spreading out from the elements of a wavefront and the envelope of these wavelets is supposed to trace out the progress of the primary wave through whatever optical system is under consideration. This is a perfectly good method in many ways, and it has done great service in the cause of college education; but it is really only a first step toward the complete solution of the problem of wave propagation. It fails hopelessly when the description of the optical system includes dimensions which are comparable with the wave length of the light.

On the other hand, in the solution

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* *The electrons incident upon the nickel crystal are emitted by a hot filament and are confined to a narrow beam by a system of apertures. The number of these electrons scattered without loss of energy in various directions by the crystal is then determined by means of an exploring collector which may be moved to any position in front of the target. These measurements are carried out in extreme vacuum.*

of problems in mechanics, by what is known as the Hamilton-Jacobi method, use is made of an auxiliary function which is of just the right form to represent the propagation of a disturbance through a medium—ordinarily an inhomogeneous medium—in accordance with the rules of Huyghens' construction. This, as has been said, is an auxiliary function. It doesn't appear in the statement of the problem; and it doesn't appear in the solution. It is generated out of the statement of the problem, and is operated upon to obtain the solution—but it is only a mathematical convenience supposedly with no physical significance. The theory of wave m e c h a n i c s converts this auxiliary function into a wave disturbance—there was nothing periodic about it originally—and regards it not only as physically significant, but as perhaps the only physically significant thing in mechanics.

From this point of view the methods of classical mechanics are seen to be analogous to those of geometrical optics. The inference is that, just as in optics, these methods will fail hopelessly when the dimensions of the system are comparable with the wave-length of the disturbance—when, for example, they are applied to atom dynamics or to the reaction between an electron and a crystal. The scale of phenomena in these cases is too small for the ordinary approximations of classical mechanics to obtain, and the true wave nature, which is assumed to be characteristic of all mechanical systems, is put into evidence through the appearance of interference phenomena.

The free and discrete electron of measurable charge and mass, is then conceived to be a group of waves—rather like a group of waves which expands over the surface when a stone is dropped into a quiet pool of water—but with this difference: the group of waves which is the electron is to be thought of as limited in all directions, so that the whole group occupies only a very small volume. This wave-group moving through an inhomogeneous medium may be adequately described in a great variety of circumstances as a charged particle moving through a field of force. Light and X-rays are also imagined to be made up of wave groups of this same general nature. They also therefore are in a sense particles, and Professor Bragg was perhaps not so entirely wrong as has been supposed.

Marking the Overload Point

By F. C. WILLIS

HOW much power will a vacuum tube amplifier deliver? This is a question of importance to engineers concerned with the design and application of amplifiers in these Laboratories and in the field. The limiting factor is neither excessive heating nor poor voltage-regulation, as in the case of electric generators; rather is it the failure of the output wave to be an amplified copy of the input. This means distortion, of a serious kind, because it introduces spurious currents which ruin the quality of transmission and cannot be eliminated. And so radio listeners are also concerned, for overloading in their receiving sets causes acute distress to anyone who has a discriminating ear.

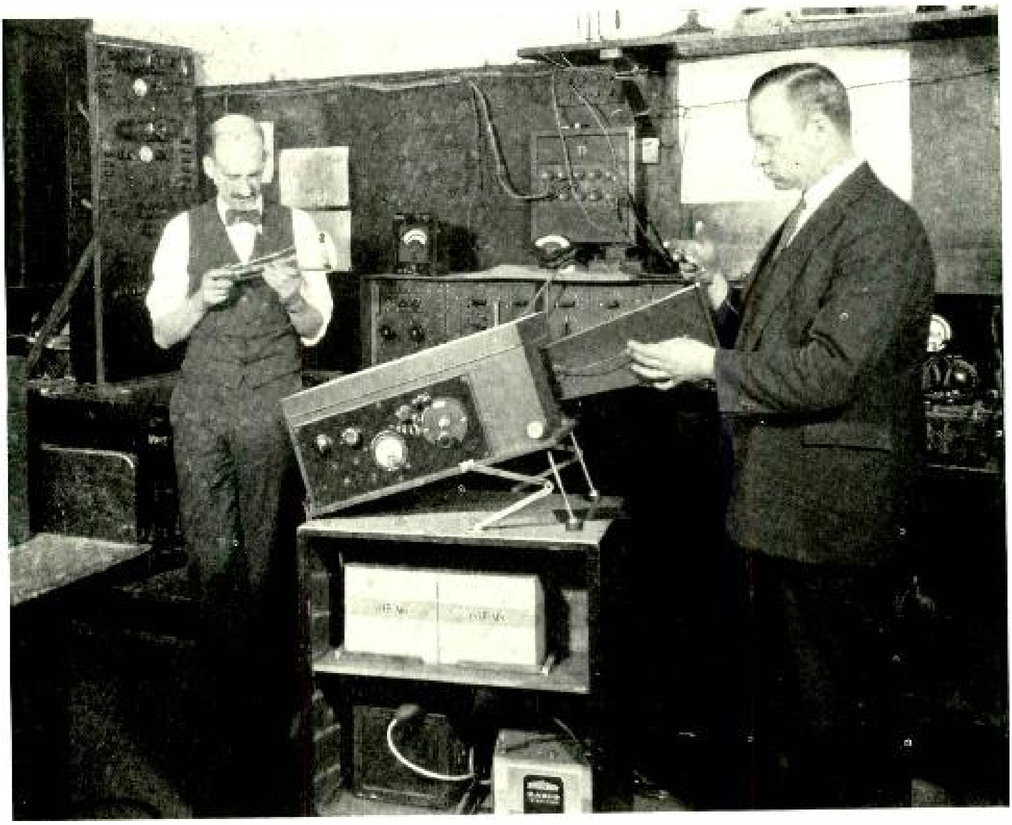


Fig. 1—F. C. Willis and L. E. Melhuish, who jointly developed a new technique for use in studying the design of amplifiers

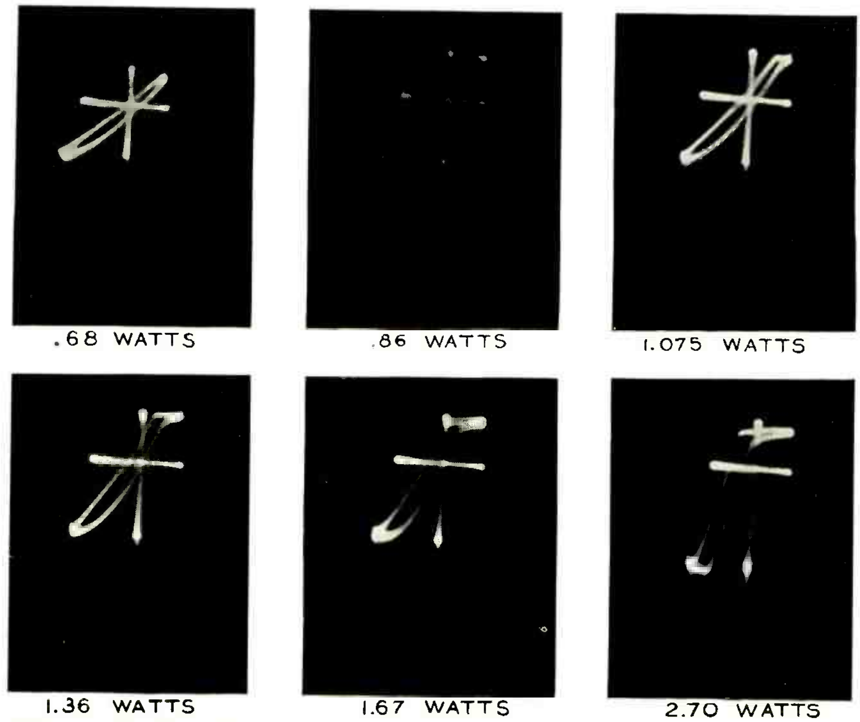


Fig. 2—Oscillograms of output vs. input for the 8-B amplifier. In the last one of its three stages was a 205-D tube with a 350-volt plate battery

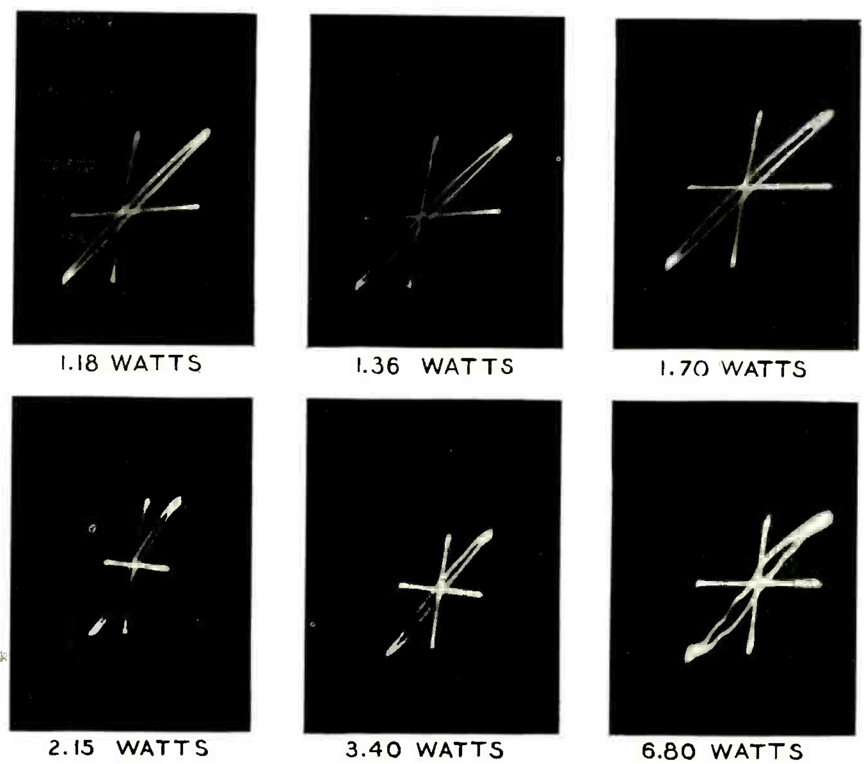


Fig. 3—Oscillograms for the 9-A amplifier—a single-stage push-pull circuit using two 205-D tubes with a 350-volt plate battery

When overloading occurs, suspicion is seldom directed to transformers and retardation coils, because they are readily, and generally, designed with a liberal margin of safety. Vacuum tubes, however, are suspected from the start; even under the most favorable conditions they cause a certain amount of distortion which increases with the load. Tubes are expensive, both in first cost and in upkeep; economy dictates that they be worked well up toward the point where distortion becomes objectionable. Although this point can be determined by ear, it is desirable to eliminate differences of opinion between observers by establishing instrumental methods and standards.

An amplifier is a relaying device in which the ratio between output and input power is intended to be a constant. The logarithm of this constant, multiplied by ten, is the gain in transmission units. When the gain begins to fall off, the amplifier is said to be overloaded. This point can be determined by measuring successive pairs of output and input powers, and plotting gain-load curves as shown in Figures 5 and 6. These curves show that gain falls off so slowly at first that an accurate determination of the starting-point is difficult.

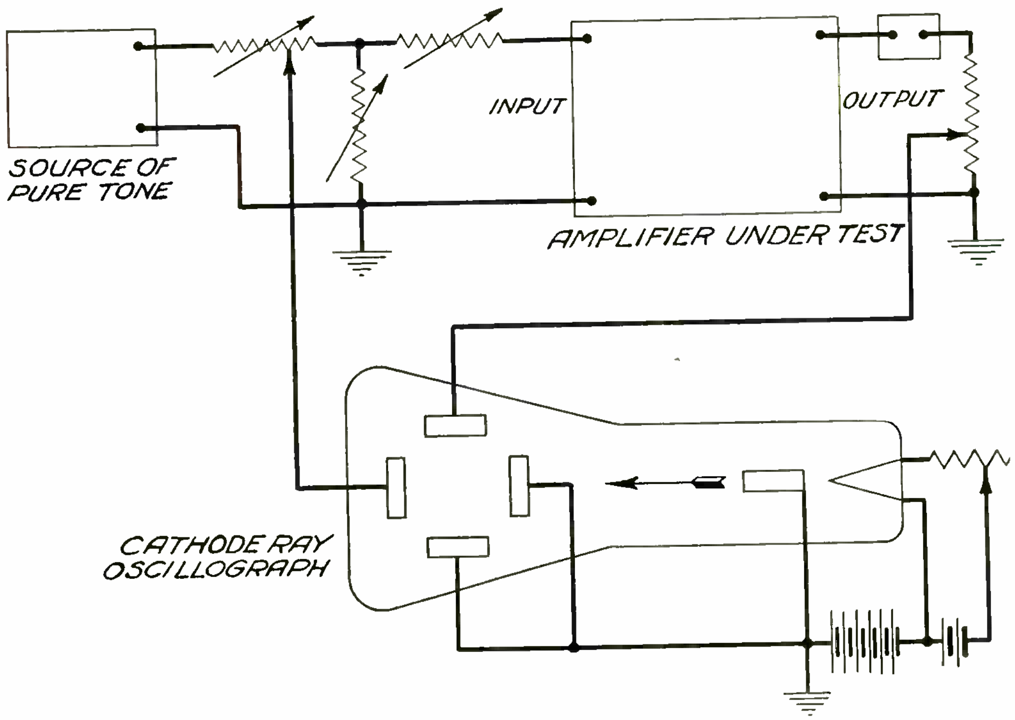


Fig. 4—How the oscillograph was connected

Another and a more successful attack can be made through the fact that beyond the overload point the amplifier can no longer respond fully to the voltage-waves impressed on its input-terminals. This results in a flattening of the tops of the output waves. The input-wave being applied to a cathode ray oscillograph* to produce a horizontal deflection of the

* *The cathode-ray oscillograph is described in* Bell Laboratories Record *for April,* 1926.

spot of light, the output was applied to produce a vertical deflection. Combination of these two forces caused the spot to trace a line diagonally across the screen. If the amplifier produced no distortion, the line was straight. But at a definite power output, one or both ends of the line would bend toward the horizontal. This effect is seen in the oscillogram marked ".86 watts" in Figure 2, and more plainly in that marked "1.075 watts." A similar effect is shown in Figure 3 at 2.15 watts. Between successive observations is an increase of about 1 T.U.; evidently a method which indicates the overload point within 1 T.U. is sufficiently accurate to be useful in carrying out a very considerable variety of amplifier studies.

When an amplifier no longer preserves, as between output and input, the stranght-line relationship just described, it will produce harmonic overtones of all the frequencies present in the input. This suggested the possibility of verifying the indication of the oscillograph by measuring the percentage of various harmonics to a fundamental wave of a single frequency. With a 1000-cycle input voltage, the harmonics were spaced far enough apart so that each could be isolated by simple resonant circuits. By measuring the output of the fundamental and each harmonic for a number of different loads, the upper group of curves in Figures 5 and 6 were plotted. At an output of .86 watt, where the oscillograms show

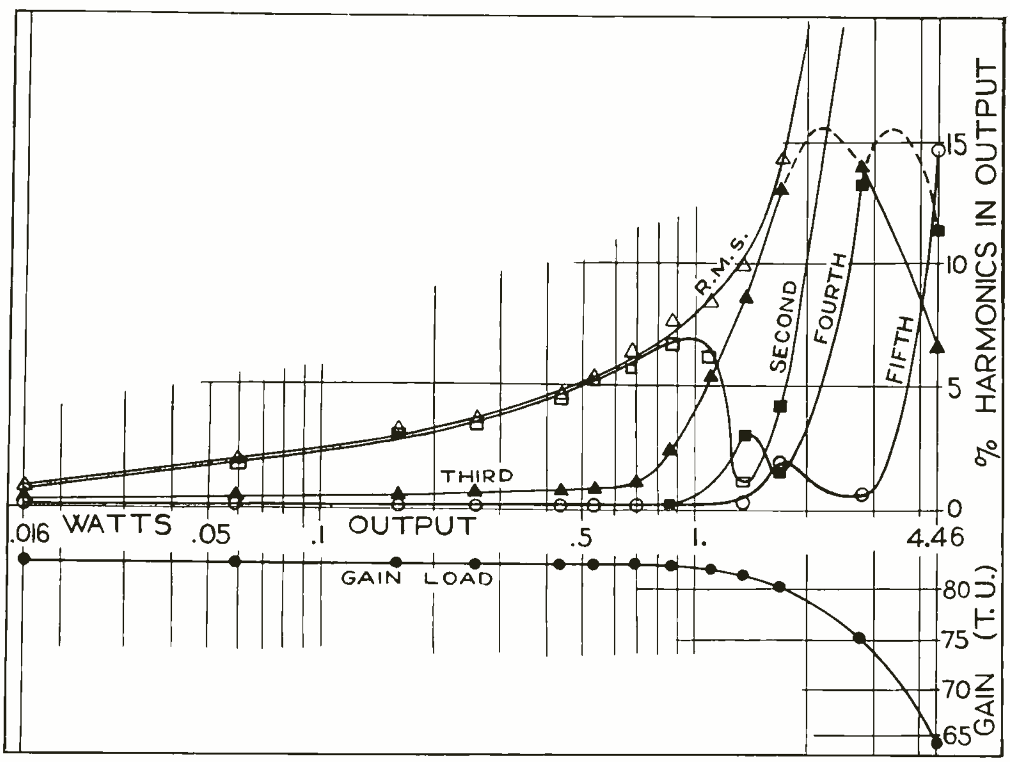


Fig. 5—Relations between output, harmonic-content, and gain for the 8-B amplifier

overloading, it will be noted from Figure 5 that the third harmonic has increased markedly from its values at lower loads. Since the second harmonic was present in appreciable amount throughout the normal range, it may be assumed that the noticeable change in quality of reproduction at the overload point is due to the third harmonic.

For high-power amplifiers and for those in which it is desired to reduce distortion to a minimum, the push-pull arrangement of tubes has been used because even-numbered harmonics generated in the tubes are suppressed in the output circuit. That the suppression is quite effective is shown by a comparison of the curves in Figure 6, made with a push-pull amplifier, with those in Figure 5. The even harmonics are smaller at all loads.

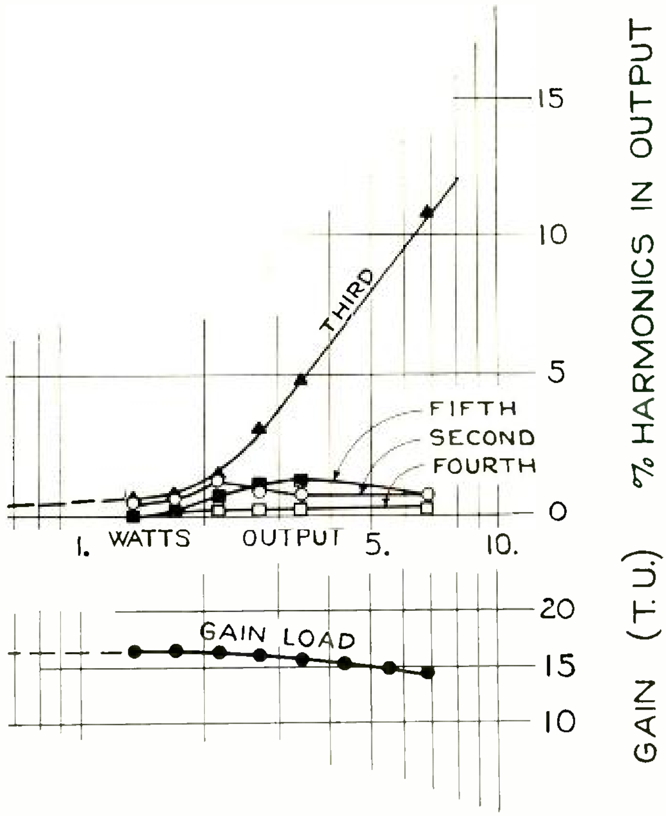


Fig. 6—On account of its push-pull circuit, the 9-A amplifier shows little or no even-harmonic content

Effect of two tubes instead of one in the last stage is also illustrated by these curves. Each amplifier employs a 350-volt supply to the plate circuit of the last stage. The 8-B amplifier (Figure 5) has one 205-D tube in that stage, and the objectionable third harmonic has made a definite increase at an output of 0.86 watt. An output of 2.15 watts however is being delivered by the two 205-D tubes of the 9-A amplifier before the increase of third harmonic has occurred. Doubling the tube and its attendant power-consumption in the final stage is seen to give a power increase of 3 T.U.

The final test of these methods is the correspondence of their indications with the judgment of trained observers as to the point at which quality begins to "go bad." It has been found that the presence of one percent of third harmonic in a 1000-cycle tone is very evident, while the second harmonic is not noticeable. Comparing the oscillograms and curves it will be seen that by the time the third harmonic has risen to a value of one percent, the tips of the figure are definitely flattened. Hence a point just before this flattening begins is an indication of the safe maximum output of the amplifier.

Mechanical Filters

By R. V. L. HARTLEY

"DEAD men tell no tales", the expression reported to have been popular among the pirates of the Spanish Main, was a recognition of some of the requirements for communication. That communication requires for its accomplishment changes, variations, or alternations in the condition at the sender and the transmission of their effects is equally obvious. It is the change and not the steady condition which permits the transmission of speech or signal; and it is the alternating components of the effect in the sender which must be transmitted to the receiver and there translated.

In electrical systems of communication the effects at the transmitter are complex alternating currents with components of a wide range of frequencies. The cause of the current is, of course, a corresponding complex motion of some part of the transmitter,—the diaphragm for example, in the case of a telephone. In this case the motion is imparted to the diaphragm by the complex sound wave which has been transmitted to the sending apparatus through the homogeneous mechanical medium of air. In other cases a complex vibration, for example of the needle in reproduction from a phonograph record, is transmitted mechanically to the sending device which converts the mechanical vibrations into electric currents. In general, then, an electrical system of communication involves at its ends mechanical devices for the transmission of vibrations and between them, an electrical channel for the transmission of alternating currents of corresponding frequencies.

Selective transmission of vibrations, whether electrical or mechanical, is a necessity of present-day communication systems. Often it happens to be desirable, however, to transmit only vibrations whose frequencies lie in a definite range—in other words, to transmit a band of frequencies. This requirement was met first for electrical oscillations by the development of so-called "electrical filters"; and more recently for mechanical oscillations by analogous devices, called "mechanical filters", in which the selection, according to frequency, is performed by mechanical parts.

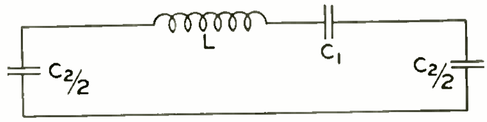
The operation of mechanical filters may be understood readily by comparison with electrical filters, and by the employment of certain electro-mechanical analogies.

In an electric circuit an alternating electromotive force, acting to set up a current, is accompanied by a reaction in the form of a counter electromotive force. The relation of this counter electromotive force to the current, as regards both amplitude and phase, depends on the nature of the circuit; but whatever the relation, the current takes such a value as to make the counter electromotive force equal and opposite to the driving electromotive force. For any particular circuit the ratio of the counter electromotive force to the current is characteristic. The ratio, which is called the impedance, is not only a magnitude but involves also a phase value which expresses the portion of a cycle by which the alternating effect lags or leads the alternating cause.

If the circuit is such that the energy supplied to it is all dissipated immediately, or all transmitted on, then the electromotive force is in phase with the current, and the impedance is a real quantity, which is called a resistance. If, however, the circuit contains a coil or a condenser, since both are capable of storing energy and subsequently returning it, there is introduced in the counter electromotive force relative to the current, a phase lead or lag. The flow of energy is not all in one direction but undergoes reversals in direction. The impedance is then a complex quantity, of which the real part is called the resistance and the imaginary part the reactance.

Analogous to this electrical system is a mechanical system which is maintained in forced oscillation by an alternating driving force. Corresponding to the current and to the counter electromotive force are respectively the velocity of the driven point and the accompanying counter force. By analogy the vector ratio of the counter force to the velocity is called the mechanical impedance of the system. The mechanical impedance, like the electrical, depends upon whether the system involves elements capable of storing energy. If such is not the case —if, in other words, the storage of energy is negligible compared to its dissipation, then the velocity is in phase with the driving force and the impedance is a "mechanical resistance." Friction and dissipational effects, in general, introduce resistance; mass and elasticity introduce reactance. When mass is set in motion the

Diagrammatic representation of an electrical filter F, receiving current from source S, and delivering to receiving element R



Details of section of filter F

Figure 1

counter force is proportional to the rate of change in velocity; the force leads the velocity in phase; and the mechanical reactance is positive. Mass is thus analogous to inductance where the counter e.m.f is proportional to the rate of change of current. Where elasticity enters, on the other hand, a restoring force comes into action, which is proportional to the displacement—that is, to the integral of the velocity. This is similar to the action in a condenser where the force is an e.m.f. proportional to the quantity of electricity—that is, to the integral of the current. The restoring force lags in one case behind the current (that is, the velocity of moving electricity) and in the other behind the velocity of mechanical motion. Corresponding, therefore, to the capacity of a condenser is the so-called "compliance" of an elastic system, which is the reciprocal of its stiffness.

Since the three elements of an electrical impedance, namely resistance, positive reactance and negative reactance, have analogies in mechanical impedance of dissipation, mass, and compliance, a mechanical analog of an electrical filter may be produced by selecting a mechanical element analogous to each element of the electrical filter and combining the elements in such a way that their interactions involve principles analogous to those of the electrical network.

The electrical filter of Figure 1, a common type, has for analog the mechanical filter of Figure 2. The latter is an early experimental model in which the driving force is set up electrically by one of the moving-armature structures which terminate the filter. A connecting rod imparts to the reeds a vibratory motion in the direction of the driving rod. These reeds, and the spiral springs with which they are connected, constitute the reactive elements of the filter. At the distant end the terminating mechanical impedance is supplied by the other electromagnetic element, which converts into electrical energy the mechanical energy delivered to it from the filter. If this electrical energy is dissipated in an electrical resistance, or transmitted away by a line, the mechanical impedance, which is thus presented to the filter through the connecting rod, will be approximately a pure resistance for the frequencies which are transmitted by the filter.

For the electrical filter of Figure 1 the band of frequencies which is passed lies between a lower limit which is set by the resonance frequency of the series branch (L and C_1) and an upper limit which is set by the resonance frequency of a section of the filter taken as a whole (that is, of L in series with C_1 and the other two capacities).

The impedance of the filter, as computed across the terminals to which the source is connected, is practically a pure reactance, independent of the number of sections involved, for all frequencies outside the limits. The counter e.m.f. and the current are a quarter of a cycle out of phase. The current, therefore, is "wattless" as the electrical engineers would say; and energy surges into the filter and out again in equal amount, twice for each cycle of the driving force. These periodic oscillations of energy are greatest between the source and the first section of the filter; progressively less disturbance extends to the following sections; and practically none reaches the terminating impedance. That is why these frequencies are said to be suppressed by the filter.

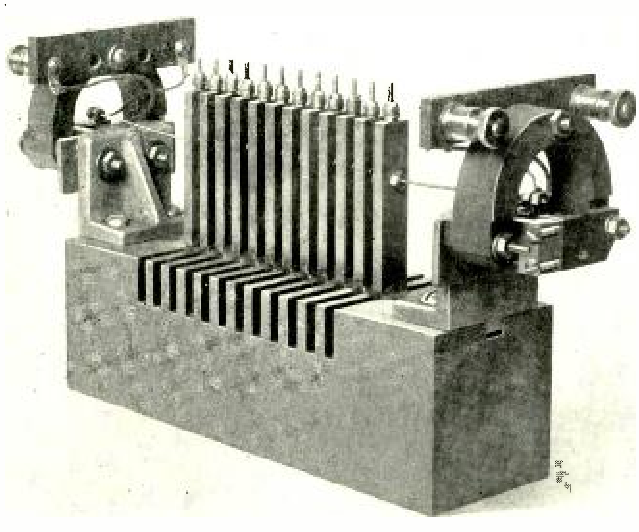


Figure 2—An early form of mechanical filter

The action of this mechanical filter is

analogous to that of the electrical filter to the ends of which are connected electrical circuits or devices which offer impedances of essentially pure resistance and of proper value. The proper terminating impedances are essential to securing the desired band selectivity of frequencies. Their quality of resistance can be, and of course usually is, obtained in the form of an effective resistance when an electrical filter is connected to a long uniform line which transmits energy on as fast as it arrives.*

The analogies between electrical and mechanical elements of reactance lead to corresponding analogies as to the interactions which occur in the sections of the electrical and mechanical filters. Whereas in the electrical circuit there is an alternating current, in the mechanical circuit there is a sinusoidal velocity. Similar to the current in the series branch, $L C_1$, of an electrical section, is the velocity of the reed in the mechanical section at its point of connection with the spiral spring. Its mass and compliance, due to inertia and stiffness, correspond to inductance and capacity.

In the electrical case the current in any one series branch divides between the next series branch and the intermediate shunt; and the current to the shunt is the algebraic difference between the currents in the two adjacent series branches. Similarly, any difference between the velocities of two adjacent reeds must equal the velocity with which the ends of the connecting spring approach or separate. The spring, in other words, serves in its compliance in a manner similar to the shunt condenser C_2 of the electrical circuit. Its variation in length is accompanied by a counter force which lags behind the velocity and tends to move the adjacent reeds in opposite directions. In this action the counter force is similar to the lagging e.m.f. across the shunt circuit of the electrical section, which tends to send currents in opposite directions through the adjacent series branches.

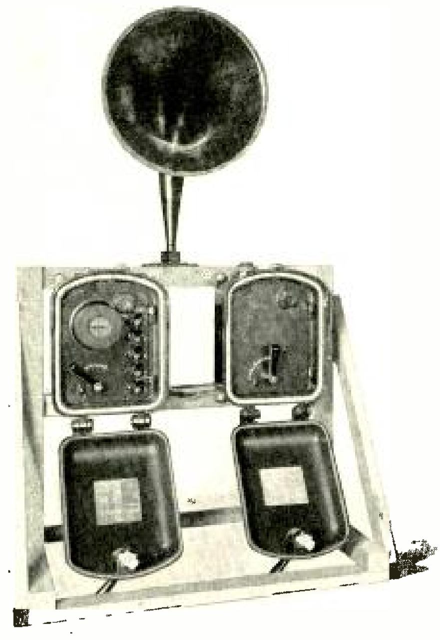
A mechanical filter, therefore, performs in the transmission of mechanical vibrations functions similar to an electrical filter for electrical vibrations. It is subject to similar requirements as to relations of its terminal impedances. If a mechanical filter is provided with electromechanical apparatus at its terminals, as was done in the experimental model of Figure 2, it may replace an electrical filter in its transmission effects.

* *For frequencies within the transmitted band the impedance of the filter, when terminated by the proper resistance, is also a resistance and of the same value as the terminating resistance, and this is the case without regard to the number of sections in the filter. This means that the flow of energy of these frequencies is continuously in one direction (and not alternately in and out as for frequencies beyond the band limits). Within each section there is negligible resistance and hence negligible dissipation of energy; so that current flows into the terminating resistance precisely as if this resistance were connected directly to the source.*

An Announcing System for Battleships

By L. E. MELHUISH

WHEN John Paul Jones commanded, "All hands to quarters", a hardy bo's'n blew the call on his little pipe and followed it up with a lusty shout down the main hatch. With the passing years, ships grew so big that it would take several minutes for a call to be sounded in every part. For a modern battleship has a total length of about



Equipment at a transmitting station, as set up for demonstration

600 feet and a width amidships of about 100 feet. It is divided into seven or eight decks on which a crew of fourteen hundred officers and men work, live and sleep. The services of about half of these men are required in various parts of the ship in the course of its normal operation and all are on duty when the ship is in action.

On a modern battleship there are three centers from which most of the operation and business of the ship are directed. These are the Navigating Bridge, from which the movements of the ship are controlled; the Deck Office where the ship's business, covering supplies and personnel, is transacted; and the Central Station, a room in the central part of the ship deeply buried under many layers of protecting armor, from which the ship may be operated even with the decks and upper structure badly damaged or under extraordinary exposure to shell fire.

Telephones in these and many other parts of the ship are interconnected through a switchboard; by means of this system it is possible to reach officers who are at definite stations. To communicate with the entire force, or to call officers who are moving about the ship, it was necessary to use bugle, bell or whistle signals, or to send out a messenger. Obviously, there was need for a telephone system which would carry a voice into every corner of the ship.

In 1916 the first system of this kind was installed on the U. S. S. Arizona. It made use of twenty-four electro-mechanical amplifier units to give sufficient energy for sixty loud-speakers. Quality of reproduction was not particularly good, but the system met a real need so effectively that further development was stimulated. This took the direction in particular of applying the vacuum tube, which had just come into use. In line with then-current practice, low plate voltages were specified, and ten tubes in parallel were used for the last stage.

With development of the Public Address System, its high-quality transmitters, receivers, and amplifiers became available for the naval announcing system. The amplifier is mounted on a rack framework in the central station, where it has the greatest protection. It consists of two stages, the last embodying two tubes in push-pull, and the first having a spare tube which is switched into service automatically upon failure of its mate. Three transmitters of the close-talking type are furnished. Each is mounted with certain control-keys and relays in a water-proof iron box; one is in the Central Station. About one hundred loud speakers are mounted in strategic locations throughout the ship. They are grouped into five circuits, which may be connected singly or together to the amplifier. This avoids disturbing those parts of the ship which are not concerned with a particular call. Control over the system is vested in the transmitter set first brought into service.

To make a call, one or more of the selecting switches is thrown, and the large handle is turned to the left. As soon as the amplifier is ready to function—a matter of a second or two—a lamp-signal appears. The bo's'n now pipes his call, and follows it up with verbal orders; or he asks Lieutenant So-and-So to call the Deck Office. Meanwhile, relays cut out the loud-speaker over his head, and also prevent any other station from interrupting him.

Alongside each station is an alarm signal box for use in emergencies. Pulling the handle half-way energizes

"All hands to quarters"; the boatswain pipes his call to every part of the ship at the same time

the system and cuts off any telephone station which happens to be in use. When the handle is moved to the end of its stroke it establishes a feed-back circuit in the first stage of the amplifier, causing an audio-frequency "howl". The resulting tone is projected by all the loud-speakers; a simple code will signal such emergency calls as "general quarters" and "fire".

Power for the system is drawn from the ship's 220-volt direct current mains. One circuit through resistance units is closed by the main switch at each telephone and alarm box; it operates relays which start a motor generator set. Direct current at 350 volts is applied through a filter to the plate circuits, and at a lower voltage to charge a storage battery. This battery is simultaneously connected to the filament and microphone circuits. On releasing the main switch, all power is cut off; but switches are provided at the power panel to keep the system continuously in operation when it is important to save the few seconds' delay which are involved in starting up the motor-generator set.

To meet severe conditions of service on shipboard, the loud-speaker horn may be fastened to a supporting bracket. The loud-speaker units are of the same type as is now used for public-address systems; in their martial environment their service is no less satisfactory than that of their garlanded and flag-draped brothers who utter the happy music of dance and song, instead of the stern commands of war.

Telephones and Research

Seventeen million Bell and other telephones, 45,000,000 miles of wire, 6,000 telephone offices, 70,000,000 wire-conversations a day, local calls completed in less than half a minute — impressive as such statistics are, they scarcely explain why our telephone service is without a peer. We lift a receiver from its hook. Something happens immediately. Every telephone on the continent can be connected with ours in ways and for technical reasons still mysterious to most of us. Repeaters, for example. * * * *They conquer all distances. They quintuple the message capacity of a pair of wires and thus save millions in copper. Research discovers a way of lengthening the life of these repeaters. The result is a saving of $1,000,000 a year.* * * * *A hundred thousand parts must be made in quantities that run into the millions. Research scrutinizes them, redesigns one and effects an annual saving of $8,000,000. It tests cords and proves that green is not so good as brown. Another saving of $50,000 annually results.* * * *

It is research of this character that has made it possible for the telephone to grow stupendously. In the laboratories lies the secret of telephone service — the laboratories where $13,000,000 is spent annually and 3,600 men and women, trained scientists and their assistants, strive unceasingly to bring more and more of us within voice-reach of one another. Without research, which foresees obstacles years before they are encountered, the telephone systems of New York and Chicago would still be scarcely more than a romantic dream.

—From an editorial in the New York Times of March 13, 1927.

Cable Corrosion

By C. D. HOCKER

ONE of the properties of lead which make it suitable as a cable sheath material is its resistance to corrosion. However, lead does not always withstand corrosive agents; there are occasional service conditions in the telephone plant which may cause a hole to be corroded through a lead cable sheath within a few months.

Fortunately, in only a few cases do underground cables experience this rapid corrosion. The total of all losses of cable due to corrosion, either slow or rapid, is very small compared to the new cables added each year. Nevertheless careful studies are made every year of a considerable number of typical cases of cable-sheath failure. The knowledge thus gained aids in protecting cables from further damage.

Laboratory and field studies disclose much about the cause of injury to any particular piece of cable sheath. Various types have been recognized, and descriptive terms have come into use: electrolytic, soil, chemical and self-corrosion.

Electrolytic corrosion is generally considered the most common type. It is due to stray earth currents from electric railway systems which employ grounded direct-current generators. These currents do not return to their source (as a power house) exclusively along the trolley rails. Instead, the current may flow part way through sub-surface metallic structures such as cable sheaths. Current leaking onto a cable generally does little harm, but at points where the current leaves the sheath and re-enters the soil or ground waters, lead is carried into solution and the cable sheath may become badly pitted. To determine if a cable already in the field is in danger from stray-current electrolysis,

Fig. 1—Electrolytic corrosion due to current leaving sheath

voltmeter measurements are made at manholes to find if the cable is positive to earth, that is, has current leaving it. If a large number of these field measurements show the cable to be positive, this condition is changed generally by bonding the cable through a metallic connection to the negative bus-bar of the power-station. Then current leaving the cable follows a metallic path instead of entering the soil directly and carrying lead away.

There are many cases of cable sheath corrosion not due to stray currents leaving a sheath. All of these appear to be electro-chemical in nature, just as is the rusting of iron. The theory of such an action is that local potentials are set up between nearby points on the surface of the metal. Then in the presence of water containing any kind of conducting salts certain of these points become anodic—that is, become points from which lead may go into solution forming a pit after a time. Nearby points become cathodic; oxygen or other negative ions are discharged and the lead is not seriously affected. There is good evidence that these dissimilar points on the surface of a metal may be produced by chance inequalities of composition, or even by mechanical strains in the surfaces of the metal.

Of this type is the corrosion due to soil waters; it is not uncommon, although such action is usually not rapid enough to penetrate cable sheath for many years. Contrary to what one might expect, the corrosive tendencies of soils do not appear to be determined by their acidity or by the total amount of water-soluble material they contain. Our laboratory studies indicate that the effect on a cable sheath is apt to be mild if a soil water contains ingredients—notably silicates—which tend to produce an insoluble protective film on the surface of the lead and thus slow up further attack. With some soils, laboratory experiments indicate that a sheath may be somewhat electropositive and still lead will not be carried into the soil by departing current because of the formation of a protective film. On the other hand certain sodium salts in the soil water may harm a sheath even when it is negative to ground. Current entering the sheath will form soda-lye; if the solution becomes strong enough it will attack the cable.

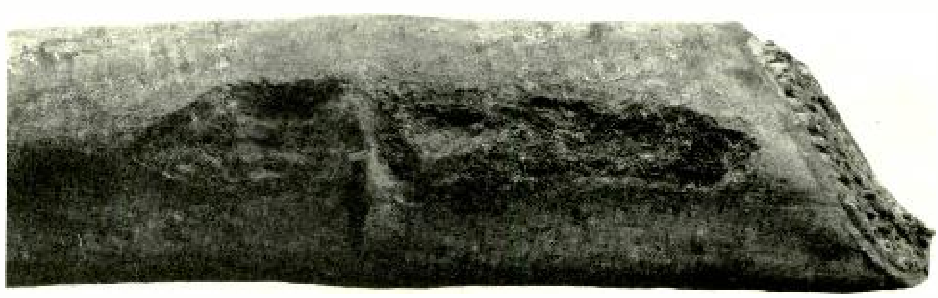


Fig. 2—Chemical attack due to alkali formed by stray current entering sheath

An otherwise useful chemical action "gone wrong" is, aside from stray currents, the most serious type of cable corrosion. White lead, an important constituent in paints, is made by exposing lead to carbon-dioxide gas in the presence of acetic acid vapor. The lead is first converted into lead acetate; this in turn is converted into lead carbonate with accompanying release of the acetic acid to renew its attack on the lead.* Carried on deliberately, this reaction forms the basis of the "Old Dutch" process of manufacturing white lead.

That something of this sort had been going on in certain cable ducts—to the annoyance and expense of the telephone company—was inferred from the lead carbonate and traces of acetic acid found on damaged sheaths. Stray currents were not the cause; evidence was that the corrosion occurred on the top of the cable at points not in electrical contact with the duct walls. It occurred only in relatively dry ducts and not in ducts frequently flooded with water: seemingly whatever promoted the corrosion was capable of being washed away. Finally, although creosoted wooden ducts are used widely and successfully in the Bell System, it was only in creosoted wooden ducts that this trouble occurred. However, there was a difference between the "good" and "bad" ducts in the wood, in the creosote and in the creosoting process.

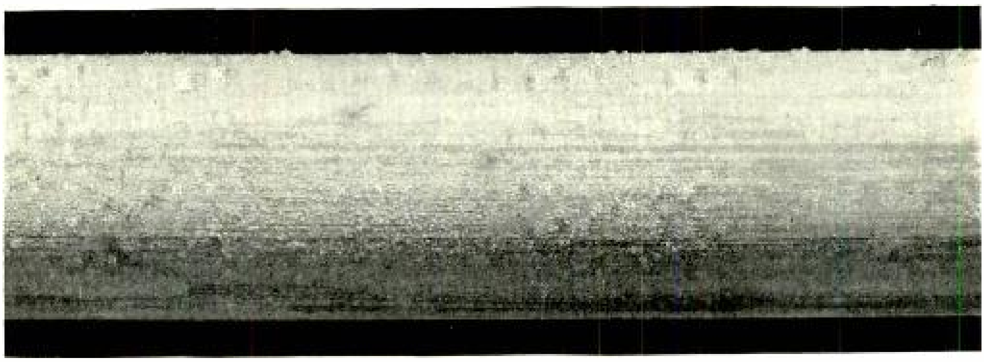


Fig. 3—White lead type of corrosion due to carbon dioxide and traces of volatile acids.

In the laboratory on exposing samples of sheath to atmospheres laden, like those in a duct line, with carbon dioxide, some slight corrosion takes place. Addition of traces of acetic vapor to this atmosphere makes the corrosion very marked. When the experiment is so arranged that sawdust of various woods can contribute their natural vapors to the testing atmospheres an indication is obtained of their relative tendencies to promote corrosion. In a similar manner there are compared the corrosive tendencies of creosote of different kinds and as applied by varying impregnation treatments. At the present time ideas are being obtained as to the relative importance of all of these factors. As a stop-gap, the Laboratories have suggestive palliative methods to arrest the corrosion of cables now in service.

** A commonly-used explanation; its accuracy is still open to question.*

The Electrolytic Condenser

By H. O. SIEGMUND

AMONG the worries of Bell, Hubbard and Sanders the supply of electric power had no place. With a permanent-magnet device serving alternately as receiver and transmitter, the power from the subscriber's lusty lungs had to suffice, for there was no way of applying more from any other source. But it was not enough. Hence the carbon transmitter in its various forms, and the need of a source of direct current. At first, each instrument had its battery of wet cells or dry. Then came the common-battery system, taking its name from the lead-plate storage battery at the central office.

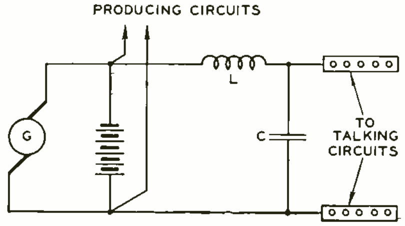


Fig. 1—Circuit schematic of a telephone power-plant

This battery, which serves as a common reservoir of energy for talking and signalling, must be charged while connected to the telephone system. Any alternating components of voice frequency in the output of the charging device will appear as noise-currents in telephone lines. Noise is objectionable; and great pains have been taken to design a generator from which the disturbing currents are a minimum. "Ripples" due to armature teeth are eliminated by a smooth surface-wound revolving iron core. Metal-gauze brushes instead of the more common self-lubricating carbon variety and a larger number of commutator segments are used to obtain smoother commutation. These and many other departures from commercial standard practice more than double the cost and size of the machines, reduce efficiency, and increase maintenance. However, the actual amount of money involved was no serious matter until machine switching greatly increased the power required for a central office. In view of the number and size of generators for such an office, it was evident that prospective savings would well repay development work in the direction of utilizing the less-expensive commercial generator.

Elimination of certain alternating currents suggests filters. Since direct current is to be passed, and frequencies in the audible range are to be

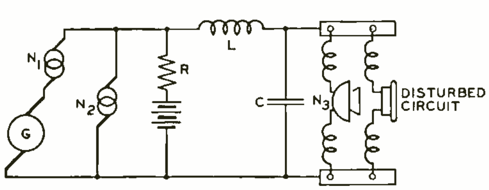


Fig 2.—Functional re-presentation of Figure 1. N_1, sources of generator-noise; N_2, noise-producer equivalent to relays, switches, etc.; N_3, transmitter of a disturbing telephone circuit

eliminated, a low-pass filter is indicated. Of such a filter a circuit-schematic is shown in Figure 1; this is transformed into the operation-schematic of Figure 2, by indicating the sources of noise and the circuit they

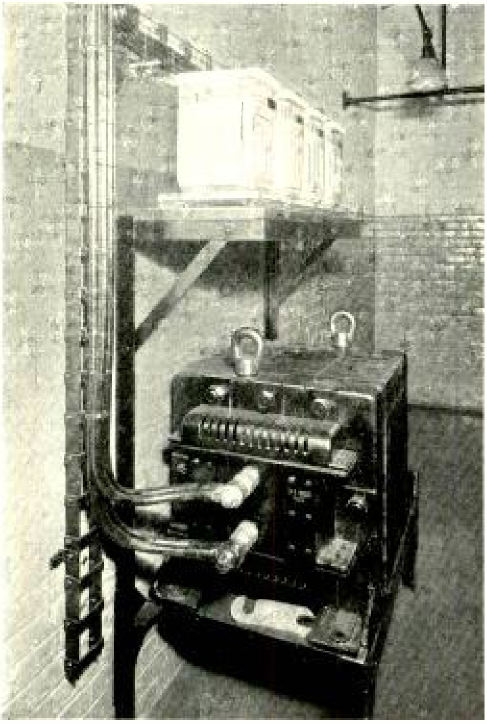


Fig. 3—A typical filter-installation. Note how little space is taken by the 4000 mfd. condenser

disturb. Evidently the combination of the reactance coil, the equivalent resistance of the battery, and the condenser forms a low-pass filter. With respect to the disturbed circuit, alternating currents from N_1 and N_2 may be suppressed to any desired extent by selecting appropriate values for L and C. Successive stages of series inductance and shunt capacity could be used, but the most satisfactory arrangement uses one coil and the required number of condensers.

Since the cut-off point of the filter is determined by the product of its inductance and capacity, evidently the pair of values to be selected are those giving the lowest over-all cost. The reactance coil must carry a heavy direct current; to limit its resistance losses, the size of conductor must be large. Its cost therefore, rises rapidly as its inductance is increased, and becomes prohibitive for more than a few millihenries. This situation is one reason for the use of condensers of several thousand microfarads; another reason is to give a path of very low impedance for the audio-frequency components of currents flowing in subscribers' lines. The condenser C in Figure 2 will absorb currents of this sort generated by the transmitters symbolized at N_3 and prevent them from flowing into other sub-

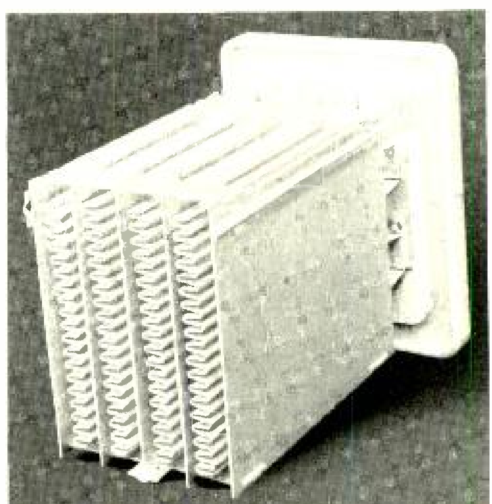


Fig. 4—Electrode structure of a condenser; corrugated plates are positive

scribers' lines. While paper-insulated condensers could be used, their cost and bulk are so great for this large capacity that attention was directed to the possibilities of the aluminum electrolytic condenser.

Certain metals—conspicuously, alu-

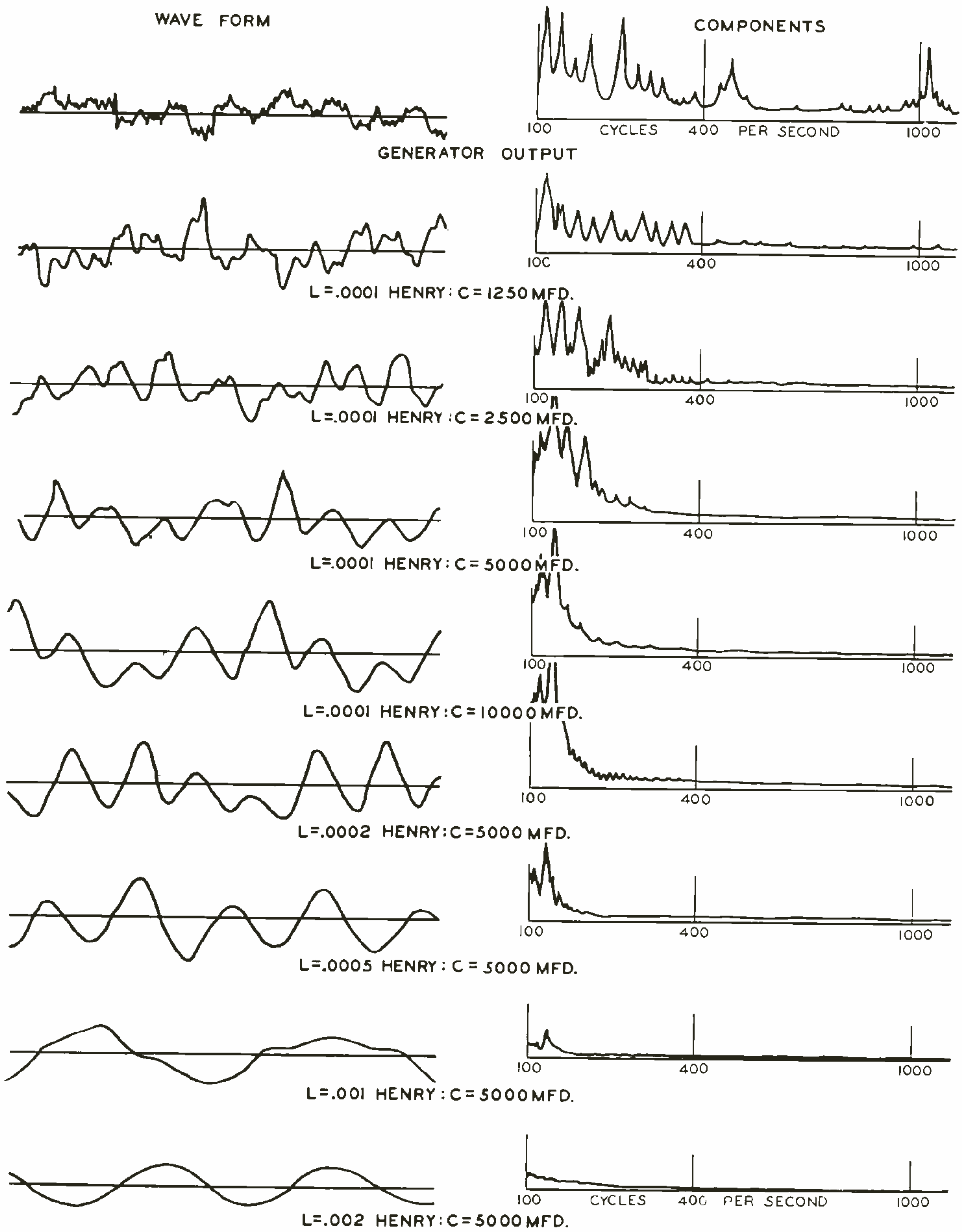


Fig. 5—How the filter changes the wave shape of the alternating component; the direct current component is not shown

minum—have the property of forming a dielectric surface-coating when immersed in a suitable electrolyte to which they are maintained electrically positive. Although the exact nature of this coating, or film, is not well understood, its properties are used in chemical rectifiers, in lightning arresters, and in condensers. The film requires some time for its formation, but adheres firmly and will last indefinitely when the metal electrode has been taken from the electrolyte, rinsed and dried. Left in the solution with no potential applied, the film slowly dissolves, but is maintained as long as potential is continuously applied. On smooth aluminum a capacity of about one microfarad per square inch is obtained with a film formed by a potential of thirty volts. Thus in respect to size an electrolytic condenser far surpasses one in which mica or paper is the dialectric. Its losses, while somewhat greater, are more than offset by savings in initial cost.

Installed in a central-office power room, the electrolytic condenser resembles a single-cell storage battery. Its plates—corrugated for the anode, flat for the cathode—are fastened to the porcelain cover of the jar. A layer of paraffin oil floating on the electrolyte prevents evaporation. For 24-volt operation, one jar has a capacity of about 1000 microfarads; reduction of capacity to 600 microfarads in 48-volt service is explained by the thicker film at the higher potential. Unlike a storage battery, it requires no routine maintenance; normally, the electrolytic action which takes place after the film is formed is negligible, and neither plates nor solution require renewal for years.

How successfully the filter eliminates generator noise is visualized in the accompanying figure. In the upper left-hand corner is seen the alternating part of the generator output; that it contains numerous audio-frequency components is evident from its jagged shape and from its analysis shown at the right. Successive additions of capacity cut out the components step by step, until finally the only one left is of about thirty cycles. At this frequency both the ear and the telephone are relatively insensitive, so conversation is not disturbed.

As the background against which our telephone speech is projected, silence is indeed golden: every increase of noise involves an increase of costly speech-power to override it. And so thin films on the surface of aluminum become in effect guardians of our quiet, confining the necessary direct current to useful channels and allowing the troublesome noise currents to pass on to their destruction.

News Notes

At a dinner marking the opening of the new Physics Laboratory at Columbia University, on February 25, President Jewett spoke in behalf of industrial research laboratories.

Dr. Jewett addressed, on March 13, the All Souls' Forum of Summit, New Jersey, on "Some Social Aspects of Universal Communication".

*   *   *   *

S. W. Dean, (D. & R., A. T. and T. Company) sailed for England to join Mr. Bailey at St. Andrews, Scotland, in testing a new installation of radio receiving equipment. Ralph K. Potter sailed for London to engage in short-wave transatlantic tests in cooperation with the British General Post Office.

R. F. Hosford, (D. & R., A. T. and T. Company) attended the Convention of the American Wood Preservers Association at Nashville.

A conference with Telephone Company engineers was attended in Philadelphia by O. M. Glunt and A. F. Gilson of the Laboratories, and F. L. Rhodes, R. A. Haislip, C. G. Sinclair and J. N. Kirk of A. T. and T. An inspection of outside plant was made under the guidance of H. B. Porter, Plant Engineer of the Telephone Company.

*   *   *   *

A series of lectures was instituted early in March in the Laboratories to present various important view-points on modern practices and recent accomplishments in the art of electrical communication. The lecturers and their subjects:

A. F. Dixon: Economics of Telephone Systems. A sketch of some of the traffic and commercial statistics and factors; showing their bearing on whether a manual, step-by-step, or panel office is the most economical for a given set of conditions.

W. Fondiller: Permalloy, its Properties and Uses. Dealing with the valuable properties of permalloy telephone apparatus and instruments.

R. L. Jones: Quality of Telephone Materials. An outline of recent progress in inspection methods as brought about by applying statistical methods and the theory of probability.

A. A. Oswald: Transatlantic Telephone. A description of the present installation, some of the problems encountered and how they were solved.

R. V. L. Hartley: Increasing Importance of Phase in Communication. How steady state phase characteristics have become important in the engineering of long cable circuits and in the application of this technique to telegraph and picture transmission.

*   *   *   *

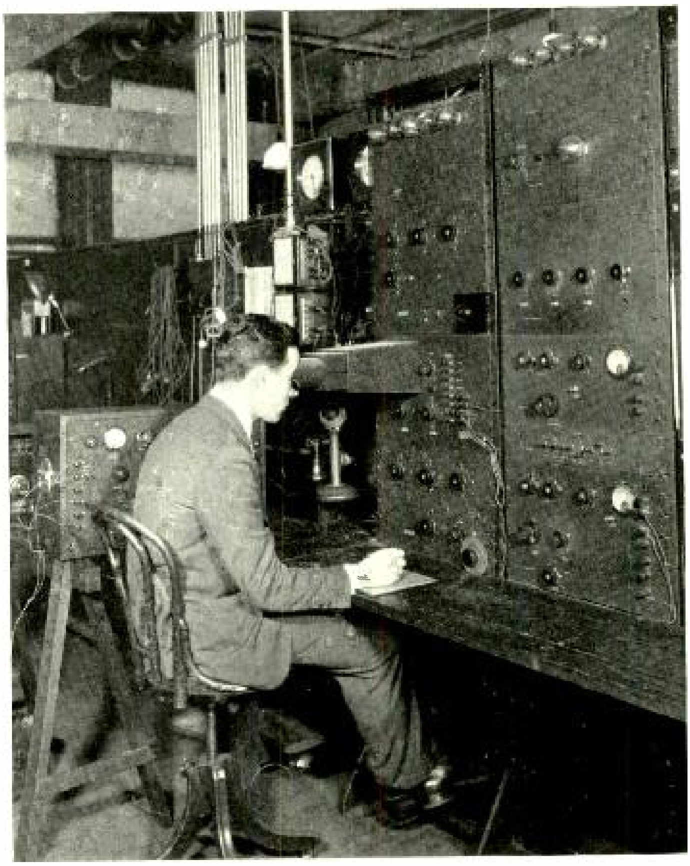
A. A. Oswald addressed the Chicago Section, I. R. E., on March 18, discussing transatlantic radio telephony. On the following day he addressed a group at the University of Illinois and on March 21 the Equipment Engineers' Club at Hawthorne.

Frequency Measurements with the Cathode Ray Oscillograph

By F. J. RASMUSSEN

A PROBLEM with which the communication engineer will always have to deal is frequency-measurement. Based upon a knowledge of the sound-frequencies in speech, systems are designed to transmit the important part of the frequency range. To check the accuracy of the work, measurements are made of the system's efficiency with currents of various frequencies. This in turn postulates an accurate knowledge of the testing frequency, through its comparison with a standard. Even more accurate must this knowledge be for measurements on filters: for example, the frequency at which the filter is observed to change its characteristic from that of transmission to that of suppression. Again, in certain measurements of capacity and inductance, a current of accurately known frequency is most useful.

During the development in the Laboratories of the cathode-ray oscillograph tube, its possibilities as a means of comparing frequencies were kept in mind as one of the objects to be attained. These possibilities follow from the fact that when the cathode-ray electrons are influenced by two alternating currents applied, respectively, to the two sets of plates. The pattern which the ray



Calibrating an oscillator by means of the cathode-ray oscillograph traces is characteristic of the frequency-ratio: for each commensurate ratio between the two frequencies, one and only one pattern can be traced.

The simplest circuit is one in which a laboratory source of standard-frequency voltage is connected through a step-up transformer and a regulating potentiometer to one pair of plates in the oscillograph. The unknown-frequency oscillator is connected to the other pair of plates. A pattern then appears on the end of the tube; if the ratio between the two frequencies is unity, one of the patterns of Figure 1 appear. Should the ratio differ slightly from unity, the pattern appears to be in motion as it changes through the successive forms shown. The ratio of the frequencies is the ratio of the number of points at which the pattern touches hypothetical lines at top and side of the figure.

Fig. 1—These patterns indicate different phase relations between two equal frequencies

Thus in Figure 2 the ratios of frequencies are 1:6 and 2:9 respectively. Here again, motion of the pattern indicates that the frequency-ratio differs slightly from the nominal value.

When the ratio between frequencies is one expressed by large numbers, it is difficult to count a large number of tangent points on one side of the pattern. Use is therefore made of a method which amounts to depicting the number of cycles made by the higher-frequency source during the time of one lower-frequency cycle. Suppose, for example, a frequency of about 30,000 cycles is to be compared with the 1000-cycle standard. The latter is applied to the oscillograph through a circuit which makes the spot of light trace an ellipse on the screen once for every cycle. On this elliptical motion is superposed a vertical oscillation due to the higher frequency. If a whole number of higher-frequency oscillations take place during a single passage of the spot around the ellipse, the upper pattern of Figure 4 will be seen. If, however, there is just a little less than a whole number of oscillations, then at a given epoch in each low-frequency cycle the spot will not quite have reached the place it had reached in the preceding cycle, and the pattern will seem to revolve. Practically, the unknown oscillator is adjusted until the pattern is stationary on the screen; the wavelets are counted, and their number is the ratio of the two frequencies.

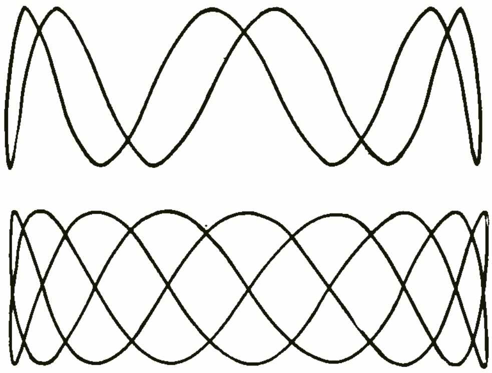


Fig. 2—Two patterns indicating frequency-ratios of 1 to 6 (above) and 2 to 9 (below)

A ratio which ends in a fraction—for example 15½:1—may be rationalized by multiplying by two, becoming then 31:2. This means that only in each *two* passages of the spot around the ellipse will the pattern close upon itself, having meanwhile made thirty-one oscillations. The pattern is the lower one of Figure 4; it is characterized by two wavy lines instead of one. Were there three lines, the ratio would end in 1/3 or thereby making it easier to distinguish the lines. This enlargement is effected by making the voltages applied to the plates great enough to

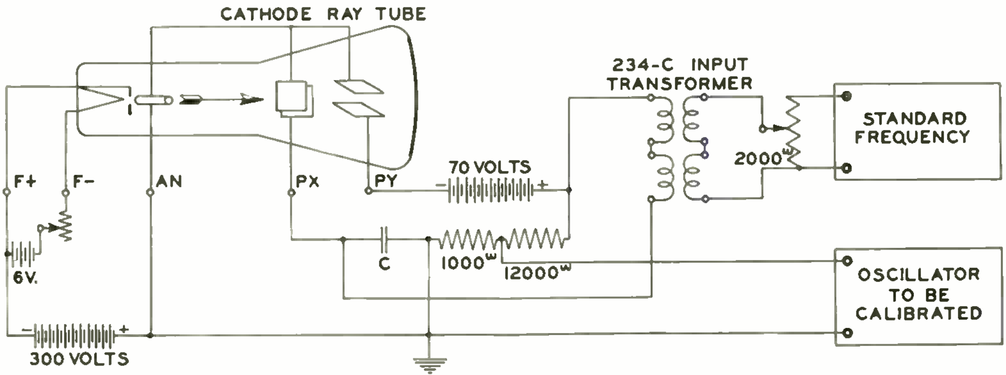


Fig. 3—A circuit in which one frequency causes the spot to describe a portion of an ellipse

2/3; four, in 1/4 or 3/4; five, in 2/5, 3/5, 4/5; and so on. Thus it is possible to get stationary patterns for a large number of ratios between the two frequencies.

How one frequency is applied to cause the oscillograph spot to trace an ellipse involves a simple phase-splitting network. It will be noted in Figure 3 that the current of standard-frequency flows through two resistances and a condenser in series. The fall-of-potential across the resistances, which is applied to plates Py, is in quadrature with that across the condenser, which is applied to plates Px. Thus the voltages across the two pairs of plates are of the same frequency, but nearly ninety degrees out of phase and the resultant pattern will be an ellipse.

Since the frequency of the "unknown" oscillator is always known at least to a first approximation, it is not necessary to count the number of waves around the whole ellipse. Advantage of this fact is taken by enlarging the pattern until only a part* of it can appear on the screen, and throw the ellipse entirely off the screen. By polarizing one pair of plates with the seventy-volt battery, the ellipse is then thrown off-center until it cuts across the screen. Dur-

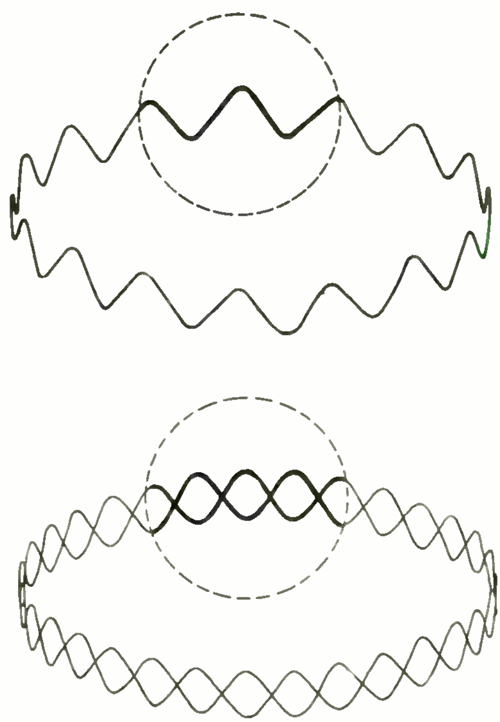


Fig. 4—One-line and two-line elliptical patterns

* *Shown inside the dotted circles of Figure 4.*

ing the greater part of each low-frequency cycle the beam of electrons is triking somewhere else than on the sensitized end of the tube;

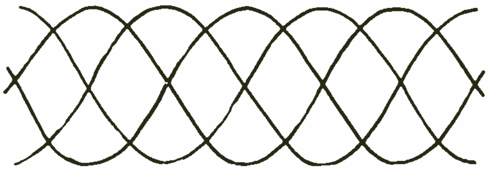


Fig. 5—As much of a four-line pattern as appears on the oscillograph tube

but it is visible for long enough to give a clear pattern in which the number of lines can readily be counted. If then one is working with 1000-cycle standard frequency, and an oscillator setting which should give about 22,000 cycles, one can find dial-settings on that oscillator at which one can count eight lines (22,125 cycles, five lines (22,200 cycles), four lines (22,250 cycles). From these readings, a calibration curve can be plotted from which any frequency-setting can be made with ease. The cathode-ray oscillograph thus becomes a most versatile tool for frequency-comparison, and one which is finding a growing use in Bell Telephone Laboratories.

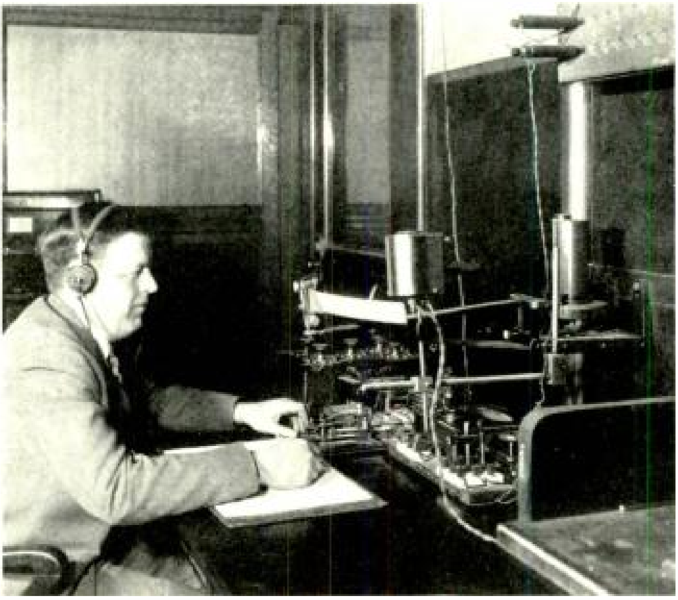
Saving for Leisure

Thrift is intelligent and persistent saving during the productive years for a sure income that will enable one to relax in later life. It means spending less than one earns, securing interest on savings, and more interest on the interest. The thrifty person does not buy things just to satisfy passing desires, but considers of equal importance the needs of the future. He is not one who merely refuses to spend money. Rather is he one who provides for legitimate expenses —present and future—and a reasonable addition to his capital, and then spends the rest of his income freely for recreation.

Measuring the Resistance of Sliding Contacts

By D. H. GLEASON

MACHINE switching is a succession of mechanical operations controlled by electrical contacts. Many of these are sliding contacts, as between brushes and commutators. A case in point is the picking of a brush, group or line on a panel selector. As the elevator-rod travels upward, a grounded brush attached to it slides over metallic segments. With the making of each contact the battery supply to the "stepping" relay is shunted and the relay releases; when the contact is broken the relay again pulls up its armature. This cycle is continued until the stepping relay has operated a predetermined number of times, when other relays halt the elevator rod. If the contact resistance between the brush and any commutator segment is too high the relay will fail to release and a wrong selection will result.

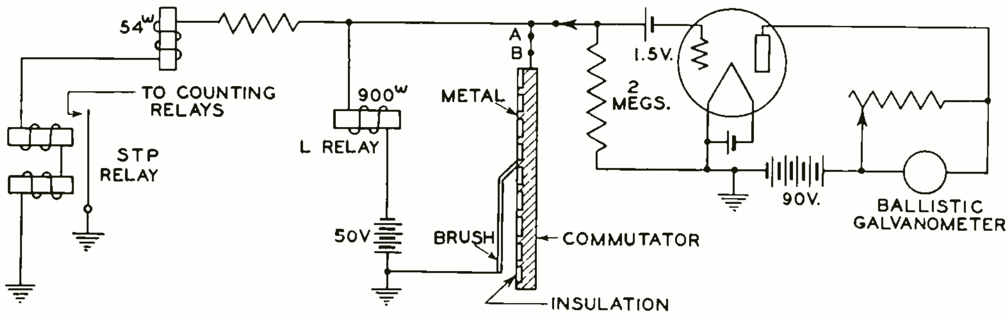

Mr. Gleason demonstrates the circuit described in this article

Inspection of the diagram shows what happens. With the commutator contact open, current flows through the winding of the stepping relay, building up a magnetic field and pulling up the armature. When the contact closes, the potential across the relay is reduced. Current through the winding falls to an appropriate value, but not instantaneously, for the energy of the magnetic field must be dissipated. Whether or not the field falls far enough to release the relay depends on the resistance of the shunt and how long it is left in the circuit.

Contact resistance varies with current flow, which in turn varies with time; hence measurements taken with the brush stationary are meaningless. It is necessary that the resistance be measured with the brush in motion and that the changing contact-resistance, including that due to any chatter of the brush, be integrated and expressed in terms of an equivalent resistance effective during the time the brush is traveling over the segment.

To avoid any changes in circuit constants, it was desirable to attach the measuring device as a shunt of very high resistance. To this end the grid circuit of a vacuum-tube voltmeter, with a resistance of two megohms, was connected from brush to contact-strip. During a measurement the brush moves across a segment at normal speed, and stops for several seconds on the insulation before passing to the next segment. When contact is made, the negative grid bias of the tube is reduced to a value proportional to the momentary resistance of the contact. Current then flows in the plate circuit, which contains a ballistic galvanometer. Since the "make" interval is so short, the entire current-pulse passes before the galvanometer deflects appreciably. The total deflection is therefore proportional to the integral of current-flow with respect to time, and in the last analysis to the integral of contact-conductivity over the "make" interval. The apparatus is calibrated by inserting a known resistance at A-B, Figure 2, moving the brush over a clean commutator segment at normal speed and noting the deflection.

To save the observer's time, there was substituted for his eye the "electric eye"—a photo-electric cell. This was so associated with relays and a message register that a failure was tallied for every time the beam of light indicated a contact resistance greater than so-and-so-many ohms. Other apparatus controlled the passage of the brush over one segment after another. When the contact was made, the galvanometer deflected until it operated the photo-electric cell —or failed to do so—and thus registered the fact of success or failure.



The circuit for measuring resistance of contacts between brush and commutator

Contact resistance is governed by many factors, some of which were thought to enter but seldom. To be sure that all these factors were represented, it was necessary to make a large number of readings. After considerable experience had been gained, it eventually showed that contact resistance was due to factors which appeared so regularly that only a moderate number of readings was necessary under each set of conditions. This fact made the photo-electric cell and its registering circuit superfluous and they have been replaced by direct observation.

Tests of contacts after they have been exposed to wear, humidity, and dust have yielded valuable information as to the effect of these factors on performance, and as to the effectiveness of proposed remedies.

In the Month's News

LECTURES and demonstrations by members of the Laboratories technical staff were given before a number of organizations during the last month. At a meeting of the American Chemical Society in Richmond, Virginia, F. F. Lucas demonstrated the use of ultra-violet high-power microscopy in studying the physical structure of iron and steel. He compared the results obtained by this method with those gotten by visual-light microscopy.

Included in the series of public lectures which are being given this spring at the University of Pennsylvania were two by H. E. Ives on the transmission of pictures by electricity. At the United States Naval Academy at Annapolis, D. G. Blattner gave a demonstration on noise and its effect on hearing; and H. C. Snook spoke on audition and the acoustics of noise.

Several lectures were given at the Massachusetts Institute of Technology. T. C. Fry spoke to the Mathematics faculty on the engineering applications of the theory of probability, and to the Physics faculty on "Plane Light Waves." R. V. L. Hartley and J. W. Horton addressed the communication colloquium on "Frequency Relationships in Electrical Communication".

H. O. Siegmund discussed before the Charlotte Emerson Browne Club of the Oranges the fundamentals of speech and hearing, illustrating his remarks by means of phonograph records. At a meeting of the City Club of Washington, H. C. Snook described the services of Bell Laboratories to the telephone industry.

A paper was presented before the Columbus, Ohio, Section of the American Institute of Electrical Engineers and the Student Branch of Ohio State University, by S. B. Williams. Mr. Williams described briefly the systems of telephone switching used in the United States for establishing local connections between telephone subscribers, illustrating with stereopticon slides and a motion-picture film.

Two of the series of deForest radio lectures to advanced students of the Sheffield Scientific School were given by M. J. Kelly on the subject of electron tube design.

L. S. O'Roark made a tour of the Pacific coast and the southwest during January and February. He addressed students of the University of Washington, the University of California, Leland Stanford, Jr. University, and a number of other institutions, ending at the University of Missouri. At Spokane, Vancouver, Seattle, Portland, and San Francisco, he talked to Sections of the A. I. E. E., and in addition, addressed electrical societies and groups of telephone employees in several cities. The total attendance was about sixty-six hundred.

* * *

James L. McQuarrie, who for many years played a leading part in engineering activities in the Laboratories, was recently elected Vice-President and Chief Engineer of the International Telephone and Telegraph Corporation and the International Standard Electric Corporation.

For forty-five years Mr. McQuarrie has been a telephone engineer; until October, 1925, when International Standard Electric was organized, he was connected continuously with the Bell System. His work in this field started in 1882, with the Bell Telephone Company of Maine, which shortly became associated with New England Telephone and Telegraph. In 1894 he was transferred to Western Electric, of which he became Assistant Chief Engineer in 1903. When the foreign properties of Western Electric were consolidated into the International Western Electric Company in 1918, Mr. McQuarrie assumed direct charge of the latter's engineering activities. He was appointed Chief Engineer of the International in January, 1925.

James L. McQuarrie

Mr. McQuarrie has been engaged during most of his career in research and development; he is credited with a total of one hundred inventions, in addition to much general development work on machine-switching systems and in the whole field of electrical communication. He was decorated by the Emperor of Japan with the Order of the Rising Sun in recognition of his services in furthering Japanese transmission progress. During the last year he was made Fellow of the American Institute of Electrical Engineers.

* * *

E. D. Talbot, for eleven years a member of the Laboratories, in March resigned to join the International Standard Electric Corporation. Beginning his telephone career in 1905, Mr. Talbot entered the Laboratories in 1916. For a number of years prior to 1924 he was active in the engineering of overseas projects for the then International Western Electric Company. During that year he joined the staff of L. Keller in Systems Development, where he remained until his recent resignation to become a member of the engineering staff of International Standard Electric.

Work on the transatlantic radio receiver at Houlton, Maine, occasioned a visit by G. T. Lorance, V. J. Hawks, and A. Chaiclin, of the Systems Department.

E. L. Baulch spent a week at Boston in connection with circuits for testing condenser-type coil cords. J. H. Bell and G. C. Cummings have been in Washington working on improvements in equipment for handling open-wire telegraph circuits. To insure proper operation of a new multi-level hunting connector being installed in Los Angeles, Henry Howland made a visit to the Coast.

Work on straightforward trunking equipment required a visit by H. S. Shope to Rochester, New York.

Following up the plan of having Laboratories engineers spend several weeks in Hawthorne in getting a better picture of the manufacturing processes, in order to facilitate our development work, G. M. Lathrop and F. F. Meyer are now at the Illinois plant.

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From the Apparatus Development Department, F. R. McMurray and M. N. Smalley are in Chicago at the Morkrum-Kleinschmidt plant in connection with the testing of No. 14 type telegraph printers.

R. E. Kuebler is in Oklahoma demonstrating talking motion pictures for the American Telephone and Telegraph Company.

H. S. Price has recently returned from Florida, where he made a survey for a 1-KW Broadcasting Installation planned by the Chamber of Commerce at St. Petersburg. He also inspected the stations of the Miami Beach Bay Shore Company and the Boca Raton Radio Corporation.

The latest Western Electric broadcasting station to go "on the air" is that of the Jenny Wren Company at Lawrence, Kansas. The 1-KW transmitter employed was installed by W. L. Tierney. Enroute to New York, Mr. Tierney visited Youngstown, Ohio, where the Youngstown Broadcasting Company is operating one of our smaller equipments.

R. C. Carlton and A. B. Bailey are making a radio survey for the New York, New Haven and Hartford Railroad on the electrified division with headquarters at Cos Cob, Connecticut.

J. E. Harris, J. H. White and F. F. Farnsworth of the Research Department were at Hawthorne on February 28th in connection with the development of a suitable light alloy for the new handset transmitter diaphragm.

L. W. Giles was in Northampton, Mass., on March 7th and 8th to install and run preliminary tests on some special apparatus, built in the Laboratories for Dr. R. H. Gault, for interpreting speech through the finger tips.

R. R. Williams was at Hawthorne from March 10th to 16th on the Development of Submarine Cable.

H. A. Larlee was in Hawthorne from February 21st to 26th and C. R. Moore from March 14th to 19th on general instrument matters.

C. H. G. Gray was in Montreal on February 21st to supervise the installation of howler test sets at that city.

The metal sections meetings of the A. S. T. M. held in Philadelphia, March 15th to 18th, were well represented by delegates from the Laboratories. C. D. Hocker was chairman of Sub Committee 7 of A5 on Corrosion of Ferrous Metals, J. M. Finch and A. C. Walker on Committee D9 dealing with insulating materials and F. F. Farnsworth on Committee B3 on Corrosion of Non-Ferrous Metals and Alloys.

W. A. Marrison and C. B. Sutliff were at Hardy, W. Va., for a few days each the past month to supervise the installation of a new type of oscillograph in the A. T. & T. test station located there.

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During February, H. G. Eddy, D. A. Quarles, P. S. Olmstead and W. A. Boyd of the Inspection Department were in Hawthorne on regular Survey Conference work.

I. W. Whiteside, Local Engineer for the Inspection Engineering Department at Cleveland, was in New York for a few days during the week of February 14th in connection with Field work in his territory.

G. D. Edwards left New York on February 13th for a survey of the Omaha and San Francisco Field Territories. This survey will include conferences on the general situation with respect to Engineering Complaints and Questions, at Omaha, Denver, Seattle, San Francisco and Los Angeles.

During the second week of February, J. A. St. Clair, Local Engineer for the Inspection Department at Atlanta, visited Jacksonville, West Palm Beach, Miami and Daytona, Florida, on regular Field work in his territory.

An emergency application of a new type of carrier telephone system was recently made on the lines of the Southwestern Company. In order to handle rapidly increasing traffic between Amarillo, Texas, and Borger, a new oil town some sixty miles away, a single-channel carrier system was urgently needed. Through A. T. & T. the Laboratories were called upon; it was decided to use a system then being set up here for experiment. Additional material was obtained from Hawthorne and in ten days the outfit had been tested and shipped. In another ten days it was placed in operation and in the first hour handled fifteen calls.

The Laboratories' end of this job was handled by H. S. Black, F. H. Chase, R. B. Simon, and E. E. Hall; the equipment was installed by the Telephone Company with the assistance of H. V. Hunter of A. T. & T.

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The Electric Stethoscope featured a notable meeting of the Medical Society of the County of Kings in Brooklyn on March 15. H. C. Snook explained and demonstrated the instrument, which with an amplifier and horn was installed and operated by H. F. Hopkins. A clinic on heart cases was held the following afternoon, in which Dr. Paul N. White of Harvard University Medical School used the stethoscope for demonstrations. Appreciation of the Laboratories' cooperation was expressed by Dr. Thurston S. Welton, President of the Society, in a letter to Mr. Craft:

> I am writing to tell you how much we appreciated your splendid cooperation in making the last meeting of the Medical Society of the County of Kings an outstanding success.
>
> The doctors found the electrical stethophone most interesting and instructive. They were delighted with the talk given by Dr. H. Clyde Snook, who explained the mechanical workings of this device. The meeting was the largest in the history of the Society.

* * * *

A dinner at the Hotel Lafayette brought to a close the out-of-hours course in Expression conducted by

John Mills. The toastmasters were Mr. Mills, B. W. Kendall and Paul B. Findley. Speakers had been elected by vote of the class, by choice of the leader, and by lot; they were D. A. Quarles, L. D. Plotner, H. I. Beardsley, M. L. Wilson, J. H. Bell, C. D. Hocker, J. E. Cassidy, P. D. Hance, G. Thompson, T. E. Shea, A. H. Leigh and E. B. Payne. Arrangements for the dinner were handled by W. H. Sellew, M. L. Wilson and F. B. Livingston; an attractive menu and program was drawn by R. I. D. Nicoll.

* * * *

On March 15 employees who were subscribing to American Telephone and Telegraph Company Stock under the Employee's Stock Plan, received "Statements of Account under Subscription for American Telephone and Telegraph Company Stock" showing the status of their accounts as of February 28, 1927. The purpose of the statements, which the Company plans to issue hereafter on July 15 and January 15 of each year, is to provide subscribers with an itemized periodical record of the increasing value of their subscription. Such statements will be of particular value to subscribers.

These statements were issued to 1,880 members of the Laboratories having 17,550 shares under subscription with a total paid in value on February 28 of $690,979.00.

STATEMENT OF ACCOUNT UNDER
SUBSCRIPTIONS FOR CAPITAL STOCK OF THE
AMERICAN TELEPHONE AND TELEGRAPH COMPANY
UNDER EMPLOYEES' STOCK PLAN DATED MAY 1, 1921

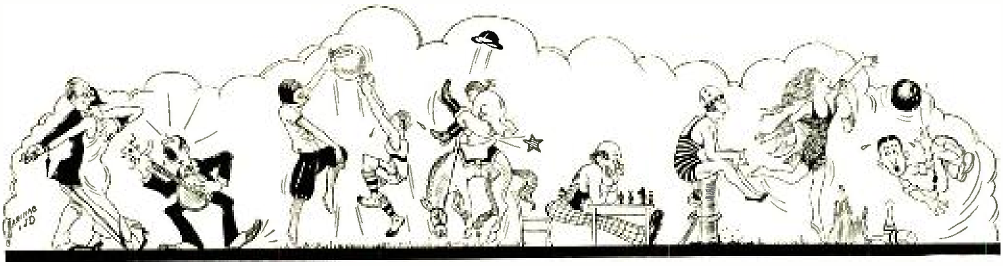
NAME JOHN DOE DATE MAR. 15, 1927

MONTH IN WHICH DEDUCTIONS FROM PAY BEGAN	NUMBER OF SHARES	PRICE	AMOUNT DEDUCTED TO DATE	INTEREST ACCRUED TO DATE AT 7% (SEE NOTE)	TOTAL CREDIT TO DATE FEB. 28 '27
May 1925	5	171.	330 00	21 90	351 90
Mar. 1926	3	175.	108 00	3 84	111 84
Dec. 1926	3	175.	27 00	24	27 24
Feb. 1927	3	130.	9 00	03	9 03
THIS AMOUNT REPRESENTS YOUR ACCUMULATED SAVINGS TO DATE ON THE ABOVE SUBSCRIPTIONS					500 01

NOTE: IF SUBSCRIPTIONS ARE CANCELLED BEFORE COMPLETION THE INTEREST CREDIT WILL BE COMPUTED AT 6% INSTEAD OF 7%

Statement of account which is sent periodically to employees subscribing for American Telephone and Telegraph stock

Favorites of WEAF fans, who will entertain at the Club dance, April 22. Above, Peter de Rose and May Singhi Breen; at left, Phillips Carlen, who will act as Master of Ceremonies; at right, the Happiness Boys, Billy Jones and Ernest Hare; below, the Ipana Troubadours



Club Notes

HAVE you seen the new programs for the Spring hiking season? We have a program planned to carry this branch of the Club Activities through to June thirtieth.

The Club offers to those qualifying a series of prizes which we hope will be of interest to all the outdoor people. There will be one emblem given to all those who, within the three-month period, walk forty miles or attend at least five of the outdoor meetings, covering at least twenty miles. The second prize will be an appropriate emblem for those walking seventy-five miles during the same three months. The "prize prize", however, will be given to those walking one hundred and fifty miles during the year beginning April 1, 1927. Come on, Hikers! Show us who are the folks who really like the out-of-doors world.

All of the April hikes are fairly easy. Sunday, April 3, there will be a campfire dinner at Saint Mary's Lake, White Plains, New York. Trains will leave New York at about ten o'clock. There will be dinner at two o'clock and a hike of approximately six miles before returning to New York. Saturday, April 23, the club will hike along the Orange Reservation to Milburn, a distance of about eight miles and will have campfire supper before returning. Thursday, April 28, after office hours, there will be a short walk—about a mile each way—up along the Hudson above Dyckman Street, with campfire supper. The almanac tells us there will be moonlight for this hike—barring clouds.

In February the Club went to Midvale on Lincoln's Birthday, and to Bear Mountain on Washington's Birthday. They were fortunate on this occasion in having snow, making it possible to spend the day skiing, snow shoeing, tobogganing and generally having a mighty fine time.

Musical Clubs

The operation of the musical organizations separately as a band and an orchestra has resulted in decided advantages to those who are interested in either type of musical recreation. Each organization now numbers between twenty-five and thirty members. The orchestra still suffers from a lack of violinists, but the disadvantage is not serious; attendance at a rehearsal of either band or orchestra is both pleasant and instructive. The impression seems to be held by some of the Laboratories musicians that these organizations are "closed corporations", or that only first-class musicians are welcomed. Nothing is further from the truth. New members are always welcome to the ranks of either the band or orchestra. It is obvious that the officers can not seek every possible member with a personal invitation, although they do so whenever they know or suspect that anyone might be interested. A number of people are now playing in the band who have not played for several years, and are finding that their enjoyment is as keen as ever. You may discover the same to be true in your case. Bring your instrument to rehearsal next Monday night in the Auditorium, 11th floor, section H—band at 5:05 P. M., orchestra at 6 P. M.—and spend a pleasant hour.

Riding

Here is a sure sign of Summer's coming. We are going to have a Rodeo of our own. This will be held some time in May, and we are trying to let everyone know about it early in order that they may practice up a bit. The full details regarding entry conditions and rules which will govern the awards will be announced later. If you want to start to get in trim, Miss Gilmartin still has some tickets for the Unity Riding Academy.

Basketball—Girls

The women's basketball team have been busy practicing and playing some outside games. While they have not beaten their adversaries, still, in the game with Dumont High School, February twenty-eighth, they kept the opposing team pretty well stopped all the way through the game. In the first half it looked as if Dumont were going to take the game easily, but in the second half some of our own shining lights began to show them that our girls knew what they were about. The score was 11—17 in favor of Dumont, but we'll win the next time.

The group has now been divided into a Girls' Rules Team and a Boys' Rules Team, with substitutes assigned for each team; although our season closed March thirty-first, everyone feels that we are ready for an A-1 start next season.

Dancing

The dancing class for women at Vecchio's Studio continues to be popular; Mr. Vecchio feels that in another season he will have to find a bigger studio to accommodate the Bell Laboratories Club enthusiasts. At the present time it appears that the members of this group will continue their activities up to the end of June, forming a new class some time in the middle of April.

Basketball—Men

The basketball season came to a close on Thursday evening, March 3, and from the interest shown throughout the entire season this sport seems to be just as popular as in previous years.

Fifty-two games were played over a period of fourteen weeks and in addition to the league games five games were played and won from other companies of the Bell System in the metropolitan district. These included the Western Electric Company, Kearny; Western Electric Company, 195 Broadway (two games); and the International Telephone and Telegraph Company.

The team representing the equipment department of Mr. Dixon's organization won the league championship and each player received as a prize a five dollar order on Alex. Taylor for merchandise. They will also hold for one year the championship trophy. The equipment team was managed by Sydney Brymer.

Bell Laboratories Club Basketball League Final Standing of Teams

Team	Won	Lost	Percent
Equipment	12	1	923
*Development	7	6	538
*Toll Exchange	7	6	538
Junior Assistants	6	7	462
Circuits	6	7	462
Tube Shop	6	7	462
Research	3	10	231

** Development won by default from Toll Exchange in a play-off for second place trophy.*

Individual Point Scores

Player	Team	Games	Goals	Fouls	Points
Maurer,	Tube Shop	11	62	12	134
Ottermann,	Equipment	13	51	10	112
De Angeles,	Research	12	46	11	103
Trottere,	Equipment	13	46	7	99
Schneider,	Development	11	41	14	96

Track

On Saturday, February 19, the 71st Regiment held its annual games and invited the Bell Laboratories Club to enter a team in the mile relay for industrial houses. H. M. Yates, track captain for the Club, held tryouts for the teams and selected a team which finished third in the race.

Since 1924 very little has been done by the Club in track or field events but if sufficient men and women are interested a track meet will be held this year.

The Bell Laboratories Club Basketball League trophy

Baseball

With the arrival of spring our thoughts naturally turn to baseball; while the Big League teams are preparing for the 1927 season the baseball committee of the Bell Laboratories Club is also planning for our departmental league. Again this year all the games will be played at Erasmus Hall Field, on Saturday afternoons. Two games will be played each Saturday. The league season will start on May 14, under the direction of L. P. Bartheld.

The executive committee of the Bell System Baseball League held its first meeting on Thursday, March 10, in the office of D. H. Carter of the American Telephone and Telegraph Company. Mr. Carter has been elected president of the League for 1927.

The League will include the following companies: Bell Telephone Laboratories; American Telephone and Telegraph Company; New York Telephone Company, Long Island Division; New York Telephone Company, Southern Manhattan Division; New York Telephone Company, Northern Division; Western Electric Company, G. H. Q., 195 Broadway; Western Electric Company, Installation Department; and Western Electric, Telephone Department.

The games will be played on Monday, Tuesday, and Thursday evenings at Erasmus Hall Field, starting Monday, May 9. All games will start promptly at six o'clock.

During 1926 the Laboratories team established a record of which we all are proud. It met and defeated teams which were composed of the pick of the ball players in the companies they represented. For three years West Street has turned out an all star team which has been unbeatable, and we see no reason why we cannot repeat in 1927.

The baseball committee is always ready to welcome new players and give them a try-out for the team. Call D. D. Haggerty or L. P. Bartheld if you wish more information regarding this activity. Try-outs will be held during April.

1.	H. M. Hagland, P. C. Rice	+ 3564
2.	I. W. Brown, R. J. Miller	+ 2516
3.	W. F. Robb, M. A. Froberg	+ 1702
4.	F. W. Treptow, J. G. Ferguson	+ 1691
5.	E. W. Rahn, V. Borlund	+ 1560
6.	J. J. Budres, L. P. Collins	+ 1065
7.	W. P. Johnson, J. Mills	+ 978
8.	C. H. Achenback, L. A. Leatherman	+ 569
9.	C. Dusheck, J. V. Moran	+ 166
10.	C. A. Smith, E. M. Smith	+ 111
11.	D. D. Haggerty, L. P. Bartheld	+ 87
12.	R. G. Kontz, D. H. Wetherall	+ 37
13.	G. T. Lorance, A. C. Dickinson	— 9
14.	E. J. Johnson, C. W. Lowe	— 53
15.	D. S. Myers, H. Keppicus	— 438
16.	C. E. Boman, J. Shea	— 452
17.	J. Dusheck, A. L. Thuras	— 1209
18.	R. N. Bittner, J. S. Elliot	— 2172
19.	G. T. Lewis, A. Zitzman	— 3546

Bell Laboratories Club team scores in the bridge match played March 14 between the Club and Western Electric, 195 Broadway. The Club won 33 matches out of 57, had 12 winning teams out of 19, and finished with a net score of + 6170