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The Manufacture of Vacuum Tubes

By M. J. Kelly

THE thermionic vacuum tubes which are sold by the Western Electric Company are manufactured in the Tube Shop of our Bell Telephone Laboratories. Fifteen different coded types of standard tubes were under manufacture in this shop during 1925. The water-cooled power-tubes that are used in the high-power broadcast stations; the peanut tube which is used in our audiometers, deaf sets and radio-receiving equipment; the small power-tubes of the public-address systems and power amplifiers; and the repeater bulbs for our voice-frequency repeaters and carrier circuits are all products of our Tube Shop.

The Tube Shop is located on the third floor of the Western Electric building at 395 Hudson Street, to which it was moved from West Street in May, 1924. At that time the demands for space in our Laboratories were so great that even with the additional space to be provided by the new section "H" the West Street building could not take care of this shop and provide room for its future expansion. A search was made for a new home, and the present location was chosen as being most suitable. This choice has proven to be wise, as the conditions have been found ideal.

At Hudson Street we are sufficiently near West Street to make use of its centralized services. For example: W. F. Johnson and his purchasing specialists are ever looking for suppliers that can furnish raw materials that will satisfy our exacting requirements. The Engineering Shop makes for us parts which would otherwise require an uneconomical installation of machinery in the Tube Shop, and J. W. Upton and his helpers are always available and frequently used for consultation on our mechanical troubles. B. B. Webb gets our manufacturing schedules from the Western Electric Company, and keeps it informed as to how we are producing. R. F. Newcomb pays all of our bills and brings around the very necessary weekly pay-envelopes. E. J. Santry tells us how much money we are spending, and to what use each bit of it is put. G. B. Thomas recruits our new people and handles the personnel problems which arise in our shop.

When the Tube Shop requires special electrical installations or changes in existing equipment, C. Cole, engineer in charge of the Hudson Street building, takes care of them for us,

Miss Lena Sproat "raising the arbor" on the stem press of the 101-*D tube*

and also gives us much help in our power plant. His experience at West Street, where he was for many years in W. B. Sanford's department, has enabled him to give us a service which it would be extremely hard to obtain in any other similar building.

In the Tube Shop the work is organized into four departments whose heads spend their entire time at Hudson Street. P. Schwerin, who has twenty-one years of service and has been in vacuum-tube work from its early days at West Street, is in charge of the operating group. J. R. Wilson, who was previously in the development group on vacuum tubes at West Street, is in charge of the manufacturing development and engineering. H. E. Crosby, who was formerly in the Building Organization at West Street, takes care of equipment design, installation and maintenance. O. J. Short, who was formerly in charge of storerooms at West Street, has the storeroom and clerical service for the Shop. These men have the able assistance of many others who have years of experience in vacuum-tube manufacture.

Our methods of manufacture and most of the equipment we use are developments in the Shop itself or by other departments of our Bell Laboratories. This has been necessary because of the pioneer nature of our manufacturing problem, which began to approach quantity production with the opening of the transcontinental telephone line in 1914 and grew with the subsequent radio and carrier demands. It might well be thought that in our manufacture of thermionic tubes we could derive much from manufacturing methods and practices for incandescent lamps. This is not true, although it is true that both the thermionic tube and the incandescent lamp have, in common, a glass envelope and wires leading through it to something inside. The similarity stops rather sharply at that point. The mechanical, physical and electrical requirements which the most simple of our thermionic tubes have to meet are legion in comparison to those of the incandescent lamp. The tremendous difference in quantity produced is another factor which prevents our taking advantage of some developments in this older industry which physically might be applicable. Machinery suitable for performing an operation tens of thousands times a day is, in general, unsuited for performing the identical operation hundreds of times in the same length of time.

A survey of the more important steps in the manufacture of one of our standard tubes will probably answer many of the questions which rise in the minds of those who use the tubes. The most common of our telephone repeater tubes, the 101-D, is chosen for description.

Historically, this tube is the oldest high-vacuum thermionic tube used in commercial communication (wired or radio) in the world. In the thermionic tube family it stands supreme, for to our knowledge there is no other standard high-vacuum thermionic tube of as long life and of as high quality. It has been used for over twelve years in the telephone repeaters of our Bell System; in fact, ever since its proportions were established by H. D. Arnold.

The first operation in its manufacture requires that glass tubing of approximately 0.6 inch diameter be cut into lengths of approximately 1.5 inch. This operation is performed on a high-speed cutting wheel mounted on special bearings so that it runs very true. Each of these lengths of tubing is the foundation for a tube. They are put successively through two machines; a flare machine and a press machine. The first puts a flared edge on one end of the tube by heating it as the tube rapidly rotates, and when it is sufficiently plastic flaring it with a carbon reamer. This flare is later necessary in sealing the tube parts into the bulb. The second machine forms "vacuum-tight" seals enclosing four wires at the other end of the tube. These wires are to provide electrical connections with the filament, grid and plate. We call this glass unit with the wire inserts a "stem press."

In forming the seal the glass is heated to a temperature where it is sufficiently plastic to be pressed around the four lead-wires. If these lead-wires are not specially shaped where they go through the glass, it is necessary for them to expand just like the glass under temperature changes.

A section of the Assembly Department, where the elements of the tube are constructed and attached to the glass stem unit

We use a wire developed for incandescent lamps called Dumet which has the same temperature coefficient of expansion as the glass. If the expansion coefficients were not the same, when the stem press is taken through temperature cycles the metal would either expand too rapidly and shatter the glass or would contract too much and tear loose from the glass. The particular action would depend upon the relative temperature coefficients of expansion and the condition of making the seal. In either event such a stem press would not be vacuum tight.

The stem press has been subjected to two successive heatings. While it cools slowly after each heating, strains are set up in the glass due to the unequal heating and cooling at different points. Glass in this condition will crack easily with temperature change or mechanical shock. To relieve these strains, the stem presses are heated in a special electric furnace as hot as possible without deforming them and are then slowly cooled to room temperature. This process, called annealing, removes the strains in the glass. The temperature cycle of these ovens is followed with recording pyrometers; and the elimination of strains is frequently checked by a special polariscope.

The annealed stem press is now ready to have attached to it the piece of glass cane (glass rod) which acts as a support for the elements. We have called this operation "raising the arbor." It is a hand operation, and requires an operator of considerable skill. The weld between the arbor and the stem is so perfectly made that when completed tubes are subjected to destructive mechanical shock tests the glass is no more liable to fail at this point than at any other. The annealing operation makes it possible for the operator to raise arbors at a more rapid rate, as the time in getting the stem press up to the temperature required to make the weld is much less.

Mrs. Martha Frykholm operates the glass-sealing machine which seals the mount into its bulb

The ten support wires for the tube elements are next inserted in the arbor. In a machine which was developed by P. Schwerin

A section of the Vacuum Pump Department

all ten wires can be simultaneously inserted. The arbor is heated at the points where the wires are to be inserted. When the operator sees that the glass is heated sufficiently, he moves two levers which advance the ten wires to the proper depth in the glass. By his next movement of the levers the ten wires are cut to proper length, and the fires turned out.

We have called this unit the "stem press and arbor assembly." It has gone through two heating operations in which the parts are heated and cooled unequally so the glass is full of strains. It is given an annealing treatment similar to that of the stem press. After this annealing it is given chemical washes, which remove any organic matter, such as grease or oil, from its surface and any oxides from the surface of the wires. The unit is now ready to have mounted on it the filament, the grid and the anode.

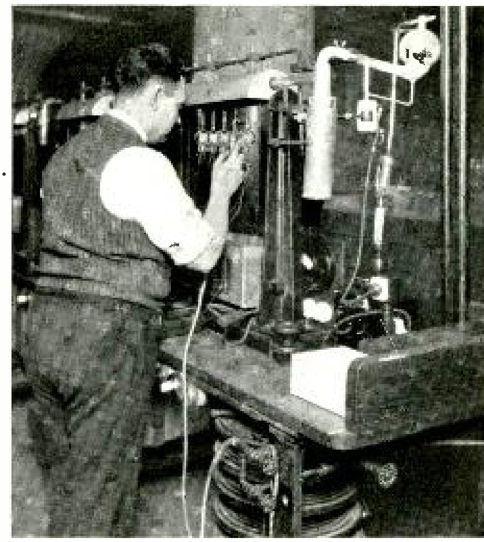
The anode is made from two stampings of sheet nickel boxed together with four nickel wires. These wires are fastened to the plate by electric welds. The grid is made from nickel wire of three different diameters. These wires are all connected together by electric welds. Both the plate and grid are formed on specially designed fixtures and electrically welded on special welding machines.

The grid and plate units, as well as all metal parts, are "pretreated" in

Miss Tessie Taddeo assembles a mount

high-vacuum furnaces and hydrogen furnaces to cleanse the metals internally as well as to remove all volatile material on their surfaces. The vacuum requirements for the tubes are such that there has to be not only an extremely high vacuum in the space within the tube, but the parts in the tube must also be so free of gas that there will be no gas freed from them during the operation of the tube. The metal parts are heated in these furnaces to approximately 1000 degrees Centigrade. By this treatment they are so cleansed that in the pumping operation it is only necessary to remove the gases absorbed on their surfaces. The time interval between these furnace treatments and the pumping operation is made as short as possible so that the amount of absorbed gas will be a minimum. The

Miss Juliette Charpin manipulates the electric welding of the grid



After completing the exhaust of a tube, B.J. McNally seals it off the pumping manifold

furnaces used in these heat treatments were developed in our Laboratory.

The filament or cathode consists of a platinum-alloy core coated with alkaline-earth metal-oxides. It comes from its manufacturing process in the form of a long ribbon. This ribbon is cut into units for each tube and shaped into its "M" form by a special fixture.

The furnace-treated grid and plate and the M of filament are assembled onto the stem press and arbor assembly by hand operations, using special fixtures for holding the parts in their proper positions and spacing them to the required accuracy. The parts are secured by electric welds to the ten wire supports of the arbor and to the four lead-in wires. We have called this unit the "mount."

The mount is sealed into a glass bulb which has a glass tube about two inches long sealed to its top. This tube is called the "tubulation." It has a constriction just above the bulb which is used at the completion of the exhaust to seal off the tube from the exhaust position.

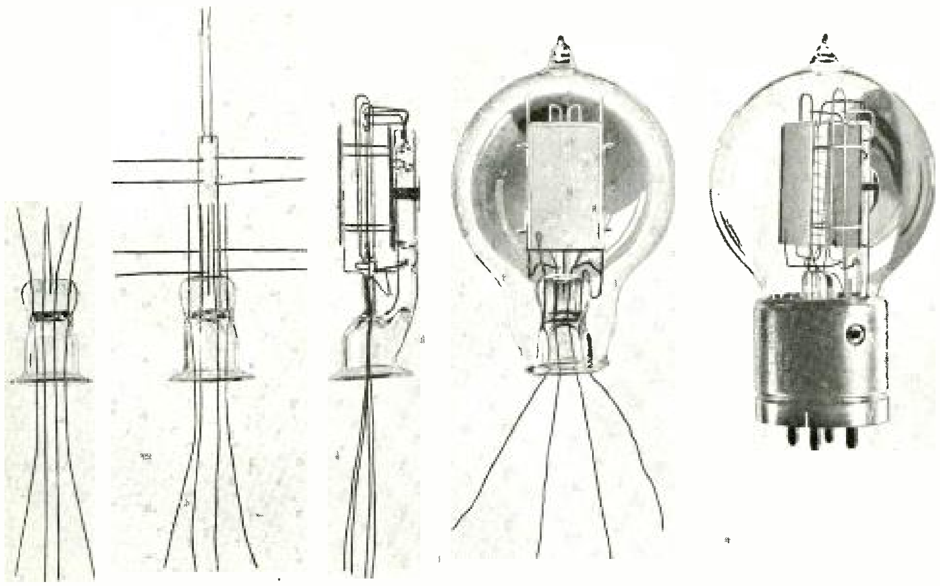
The sealing-in of the mount is done on a special machine. The flare of the stem press and the neck of the bulb are heated sufficiently for viscous flow and are united in this sealing operation. We thus have the mount surrounded by a glass envelope, except for the opening in the tubulation, which is closed after the exhaust of the tube. Four wires sealed through this glass envelope permit electrical connection with the three elements inside.

The pumping system for exhausting the tube consists of a two-stage rotary oil-pump, a mercury diffusion-pump, a liquid-air trap and the pumping manifold. The oil pump by itself is capable of pumping to a vacuum of one-thousandth of a millimeter of mercury or approximately one-millionth of an atmosphere. The mercury diffusion-pump, when preceded by the oil pumps, will pump to a pressure of one-millionth of a millimeter of mercury. The liquid-air trap acts as an infinite impedance for mercury vapor. Mercury, at room temperature, has a vapor pressure much higher than the pressure which can be obtained with the diffusion pump and much higher than can be permitted in the repeater tube. By interposing a liquid-air trap between the mercury pump and the manifold the mercury from the pump is condensed in the trap. The pressure of mercury vapor in the pumping manifold is as low as the vapor pressure of mercury at liquid air temperatures. This is lower than the required pressure for the tube.

Six of the repeater tubes are sealed onto the prongs of the manifold. An electric oven is placed around the tubes and heat is applied after a good vacuum has been obtained by the pumping system. The oven temperature is raised to as high a value as possible without causing the glass to soften and collapse. This is done in order to liberate as much gas as possible from the glass and metal parts of the tube. After a thorough baking out of the tubes in the oven, the filaments are lighted and positive voltages applied to the grid and anode of sufficient value so that the energy dissipated in them by the bombarding electrons heats them to a temperature in the range of 800 to 1000 degrees Centigrade. Gases that were not removed in the high-temperature pretreatments or that have since been absorbed are liberated by this bombardment and are pumped out. As a final operation, a small amount of one of the alkaline metals is vaporized

At the repeater test-boards Eugene C. Russell makes electrical tests on the 101-*D tube*

within the tube in order to react chemically with any oxygen or water vapor which remains and mechanically to "bury" other gases under the mirror



Steps in the manufacture of the 101-*D tube. From left to right: stem press, stem press and arbor assembly, mount, tube after sealing off pump station, and the completed tube*

coating that is formed on the bulb. The tube is then sealed off the manifold by the pump operator. The pressure in the tube when sealed off is of the order of one-billionth of an atmosphere. All the pumping equipment has been developed in our Laboratories and in the Shop. It has obtained its present form through gradual improvements during the last twelve years.

After an aging process, the tube is given a preliminary inspection to insure that it will meet all requirements; and it is then based. This operation consists in attaching the base unit to the bulb, soldering the four lead-wires to its posts and then sealing the base with a special sealing-compound. Thereafter the tube is given a complete electrical and mechanical inspection. The electrical inspection is performed on a repeater-tube test-board developed by J. Blanchard. The filament resistance, the insulation resistance, the degree of the vacuum, the impedance, the amplification factor and the amplification of the tube in a circuit similar to a repeater are all measured. The amplification in this circuit can be measured to within one-tenth of a transmission unit. The tubes that meet the standard requirements are packed and sealed in individual cartons and sent to the Merchandise Department of the Western Electric Company at Kearny for distribution to associated companies.

Selecting an Audio-Frequency Amplifier

By Donald F. Whiting

If a radio program is to be enjoyed to the greatest possible extent, or indeed at all by those who possess a critical ear, the rendition must be a true reproduction of the original sounds, without the various distortions that are common in the sounds emitted from most receiving sets. Since distortions may be introduced by both the transmitting and receiving equipment, to reduce such effects to a minimum, the broadcast listener must select his receiving apparatus with intelligent care and then favor those broadcasting stations which transmit programs in an undistorted manner. The audio-frequency amplifier, unless it is carefully chosen, is likely to be one of the principal offenders in the introduction of distortion into the receiving system.

The audio amplifier must produce a considerable effect; and a number of factors influence this very important matter of its adequate output. The provision of a copious supply of electrons from the filament of its vacuum tube is essential. By increasing the plate potential and adjusting the grid bias * accordingly, the power output may be increased about as the square of the grid potential. Since an increased plate current will flow, and sufficient electrons must be available, this may require increased filament current. No attempt should be made to determine the best filament current and plate and grid potentials by the usual method of listening to the relative loudness as each of these is varied, for this method will not give the optimum conditions. Although the output power may be increased by increasing the filament current and the plate and grid potentials, this will also shorten considerably the effective operating life of the tube. A small increase in the filament current will decrease the life of a tube by a disproportionately large amount. The proper filament currents and plate and grid potentials are usually determined by the tube manufacturers, and the length of tube life resulting from those conditions can be determined by the manufacturer only as the result of most exhaustive tests.

As long as the potential of the grid is negative with respect to that of the filament, the power consumed in controlling the grid potential of a vacuum tube is inappreciable. Advantage of this fact may be taken through the use of an input transformer, by means of which the available voltage may be increased to several times its original value before being applied to the grid. If, over the range of frequencies to be

* *There is a definite grid bias which is most desirable for every plate potential; the one varies almost directly with the other. A good approximation to the numerical value of the optimum bias can be obtained by dividing the plate potential by twice the amplification constant of the tube. In case this constant is unknown, an approximation of the optimum bias can be obtained by determining the value which gives a plate current of about one-third the value which flows when the grid bias is zero.*

transmitted, the reactance of the primary winding is large with respect to the effective resistance of the primary circuit, including that of the preceding tube, practically no distortion need result from the use of the transformer; but, if this relation is not maintained, frequency discrimination will result at usually the lowest and the highest frequencies. This type of distortion is most common when small or cheap transformers are used, especially those having a high voltage ratio. To avoid such distortion, select an amplifier equipped with audio-frequency transformers which are the product of reliable manufacturers, and are of ample proportions in their windings and in their cores for the core material used. In general, it is desirable to limit one's choice to transformers available at the present time which have a voltage ratio not exceeding 1 to 3.

An output transformer is desirable if the impedance of the loud speaker does not suit that of the final tube or tubes, if the plate current of the final stage exceeds the value which can be passed through the loud speaker without impairing its operation, or if the plate voltage in the final stage exceeds that which should be on the cord connecting to the loud speaker or that which is safe between windings and frame of the loud speaker. Comparatively little frequency discrimination is introduced by the use of a well designed output transformer, especially if its core is butt-jointed or includes a small air-gap to diminish the magnetizing effect of the plate current.

When considering the choice of an audio-frequency amplifier, from the standpoint of the distortion which it is likely to introduce into the system, attention should be directed toward the loud speaker; for it must be remembered that whatever comes out of the amplifier must pass through the loud speaker before it is heard, and, no matter how near perfection an amplifier may be, its merit cannot be utilized if other apparatus is present which distorts that which enters or leaves the amplifier.

The impedance of a loud speaker of the type more generally used at the present time varies considerably with the frequency, and is highly reactive. While there are several circuits by means of which such varying impedance may be coupled efficiently to the tube impedance over a wide frequency range, they have not yet found their way into commercial practice. It is customary to connect a loud speaker to the tube directly, or to match its impedance at a single frequency by connecting it through an output transformer of the ratio proper for that particular frequency. If the impedance matching is done at either the very low or the very high frequencies, the loss resulting at the other end of the range is excessive. To avoid somewhat the impairment in the quality of reproduction resulting from this condition, the impedances are usually matched at some intermediate frequency.

Unfortunately, many manufacturers employ no output transformer. This results in matching at a frequency where their loud speakers are already relatively over-responsive, and contributes to the "tinny" sound commonly emitted from most loud speakers. The same effect is also produced by the use of cheap, poorly designed audio-frequency transformers, by resonance in the loud-speaker diaphragm, or by a horn too small or improperly shaped. It is practically never due to the material of which the horn is made. Lack of negative grid-bias, and over-loaded vacuum tubes are causes of the rattling sound noted when a loud speaker* which is efficient at high frequencies is operated from a poor amplifier.

The power required to operate a loud speaker in a satisfactory manner is many times that required to produce satisfactory response in a pair of head-phones. It depends upon the volume of the space to be filled, upon the amount of interfering noise and upon the individual tastes of the listeners. Under these varying conditions the ratio between loud-speaker power and headphone power may range from 1,000 to 100,000 times. The mean value of 10,000 times is usually considered satisfactory for living-room conditions.

An amplifier is considered to be delivering its maximum undistorted output either when any increase in this power results in the production of currents of extraneous frequency exceeding a certain allowable percentage, or when the relation between the output and the available input ceases to be linear. The capabilities of an amplifier should be such that when the desired power is being delivered the maximum output of the amplifier is reached only on the "peaks" or the loudest portions of the rendition. Therefore, because of normal power-fluctuations during a program or during even a single selection, a sufficient margin should be allowed between the maximum power capabilities of the amplifier and the average operating power. The difference should be dependent somewhat upon the type of program.

* *Such as the Western Electric No.* 540 *or* 548 *cone-type loud speakers.*

The required output-power capabilities may be obtained in an amplifier by the use, in the final stage, of a tube which is capable of giving the necessary power throughout a reasonable operating life, and by operating under conditions of filament current, grid and plate potentials, and load impedance, which are optimum for the tube and suitable for the output desired. If the desired result cannot be obtained by the use of a single tube of a given size, and if the employment of a more powerful tube involves apparatus which for any reason it is not desirable to use, it may be possible and more convenient to obtain the necessary power by the use of two or more tubes connected either in parallel or in push-pull relationship or in combinations of the two forms. The push-pull circuit is usually preferred over the parallel arrangement on account of its capacity for delivering greater power with less distortion, owing to its tendency to suppress even-numbered harmonics. In general it is not advisable to use more than four tubes in the final stage; beyond this point the apparatus gets very cumbersome for a relatively small increase in power.

The second requirement of an amplifier is its capability of delivering a relatively large output under control of a small power available at its input terminals. This quality of an amplifier is called its "gain," and may be defined in terms of the ratio between the output power of the amplifier and the corresponding power available at the input terminals. Since in a well designed amplifier the maximum undistorted output is determined by the tubes in the last stage, any attempt to increase the output beyond this amount either by increasing the gain or the input is futile, and will only lead to overloading, and hence distortion. The total gain of an amplifier should be distributed between stages in such a manner as to secure the most economical use of tubes. For each stage a tube should be provided whose maximum undistorted output is safely above the maximum power required at that stage to give maximum undistorted output from the last stage.

Since more gain is usually required than can ordinarily be obtained from a single stage of amplification, some means must be provided for coupling between successive stages. Similar provision must also be made between the detector tube and the first amplifying stage. There are three forms of coupling in common use and each has certain points of merit.

The resistance-condenser type of coupling, if properly used, results in nearly distortionless amplification down to a very low frequency. However, the "B" battery voltage must be about twice the voltage required between the plate and filament of the tube. Unless tubes of high amplification factor are used, the resulting gain is very low, being in any case about two-thirds of the amplification factor of the tube.

The inductance-condenser type of coupling, if the inductance coil is of proper design, also results in nearly perfect coupling down to a very low frequency. The disadvantage of the resistance-condenser coupling with respect to the high plate-supply voltage is eliminated by the use of the inductance coil. The gain is only slightly less than the amplification constant of the tube, but is still low unless tubes having a high amplification factor are used.

The transformer type of coupling may result in good, indifferent or poor results, depending upon the quality of the transformer used. There is ordinarily no merit in using different types of input transformers in the successive stages of an audio-amplifier, although this practice is often followed. The exceptions, of course, are in the case of the push-pull circuit and in cases where the impedances between which the separate transformers work differ considerably among themselves, but this latter condition is not usual in receiving sets. Although the coupling obtained with a transformer is not ordinarily as good at extremely low frequencies as that obtained by the two preceding systems, it can be made good enough that no perceptible loss in the quality of the bass notes can be sensed, and the advantages to be realized by transformer coupling usually more than offset the disadvantages. In fact, by proper construction the latter may be reduced nearly to the vanishing point.

The advantages to be gained by transformer coupling are first an increase in gain of several times over that possible with the other forms, and second the elimination of the condenser and the grid leak necessary with the other forms. The principal disadvantage lies in the tendency toward relative inefficiency at the lower frequencies.

Some of the better grade input-transformers of relatively large proportions and low voltage ratio which have recently appeared upon the market are quite satisfactory in this respect. On the other hand, some widely-advertised receiving sets are equipped with audio-frequency input transformers which are so inefficient below 1000 cycles that the very low frequencies which reach the loud speaker are considerably less in energy than those in the 1000 cycle region, in spite of the fact that in the original music* they may have been sixteen times as great. The result of this is that the output power of the final stage needs to be only one-sixteenth that which would be required if the lower frequencies were transmitted efficiently, but the effect of such distortion is to produce the tinny "canned music" which is the characteristic product of cheap radio sets.

A concrete idea of the absolute magnitude of the output-power capabilities and requirements as to gain which have been found to be desirable for the average home may be given as follows: Assuming a loud speaker similar to those now in general use, an amplifier which can deliver to a resistance load a single-frequency power of one watt in practically undistorted form will possess all the power which is necessary for most purposes. This figure includes the allowances which have been made to take care of the peaks occurring in different types of music and also the loudness at which it is usually desirable to listen to these different types. A single tube, having an amplification constant of 7 and a filament emission equivalent to 60 milliamperes, to the plate of which is applied a positive potential of 350 volts, and to the grid of which is applied a negative potential of 27 volts, both measured from the middle of the filament, is ordinarily capable of fulfilling this requirement.* It is just as sensible to try to carry a twenty-ton load on a toy wagon as it is to attempt to operate a loud speaker of the types now in general use from the output of a tube designed for use with headphones.

Since the maximum undistorted output energy from many detector tubes does not exceed a few microwatts, it follows that the factor by which it is necessary to multiply the energy delivered by the detector to obtain the energy which the final stage must be capable of delivering, is between 100,000 and 1,000,000. This required gain can usually be obtained from two stages of amplification with transformer coupling, whereas three to five stages are usually necessary when the other types of coupling are used.

Tests made in rooms of various sizes with loud speakers driven by audio-frequency amplifying systems, capable of delivering considerable power without overloading, have shown that in each room and for each kind of program there is a general agreement among listeners of average

Speech power falls mostly within the frequency limits of 64 and 7000 cycles; and reaches a maximum in the vicinity of 170 cycles, although the maximum loudness sensation occurs at frequencies in the vicinity of 1000 cycles owing to the increased sensitivity of the ear. The ratio of the speech power occurring in the vicinity of 170 cycles to that occurring in the vicinity of 1000 cycles, is approximately 16 to 1. Power in musical sounds is largely distributed over a band of frequencies from 32 to 10,000 cycles; and, since the ear is deficient at the lowest frequencies, such tones must be played with greater intensity in order to be heard. However, due to practical limitations in the size of instruments, the maximum power occurs usually in the vicinity of 64 cycles, notes lower in fundamental pitch consisting mainly of their partials. The ratio of the power occurring in musical sounds in the vicinity of 64 cycles to that occurring in the vicinity of 1000 cycles is, as in the case of speech sounds, approximately 16 to 1.

If the optimum relations as to the grid bias and load impedance are adhered to, the maximum undistorted output power of the tube in watts may be estimated as the square of the plate potential in volts divided by thirty-six times the internal alternating-current impedance of the tube expressed in ohms. In case the internal impedance of the tube is not known, an approximation of the power output in watts may be taken as one-tenth the product of the plate potential in volts and the plate current in amperes.

hearing as to the most pleasing loudness. Tests which were made with the listeners giving their entire attention to the program indicated that the most pleasing loudness corresponded to the volume at which the observers were most accustomed to listen to that type of sound in its original form. Where the program was to be a background for conversation, a somewhat lower volume was preferred.

Volume control to suit the tastes of the listener may be provided through taps taken off the secondary winding of the first audio-transformer or by means of a 500,000 ohm potentiometer connected across this winding. It should not be accomplished by any conditions affecting the tube constants such as changes of filament current, plate voltage or grid bias, nor by simple shunt or series resistances, nor by taps on the primary of any audio-frequency transformer. Compensation for varying field strengths of different broadcasting stations should be made ahead of the detector tube.

To obtain a capacity for undistorted output of about one watt, it has been found necessary to furnish nearly twenty watts to the tube in the final stage of the audio-frequency amplifier. Since fully half of this power is expended in the plate circuit, and must be furnished from a high-voltage source, the use of batteries for this purpose is expensive and often inconvenient. Use should preferably be made of the house-lighting service for supplying this power through some form of rectifier and filter system. By proper apparatus and circuits, the use of this power may be extended to furnish all of the currents and potentials required for the audio-frequency amplifier and for the radio set as well. However, it is not always possible to do this merely by the addition of auxiliary equipment, for extensive changes in the wiring and apparatus of the amplifier are often necessary. In fact, the difficulties to be encountered in this direction often preclude the attempt. Consequently, when selecting an audio-frequency amplifier it is advisable to give considerable thought to the question of power supply and to favor amplifiers into which adequate power-supply systems have been incorporated.

The 6025-B Amplifier

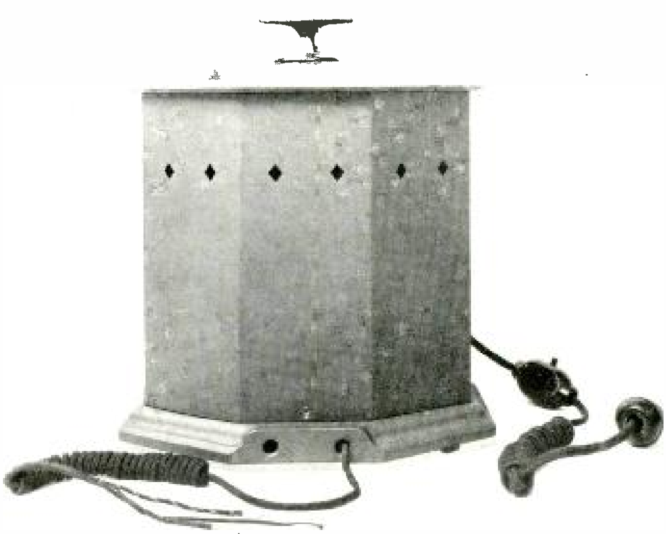
By Paul H. Pierce

TOWARD greater naturalness in the received program, public taste and radio apparatus have developed side by side. Satisfied in the early days of broadcasting with a range of pitches comparable to the three and a half octaves of the phonographs then in current use, radio listeners have learned that a much wider range is desirable. Coincident with this change in taste, and indeed as one probable cause, is the development in our Laboratories of systems to reproduce sounds covering a range of five or more octaves. Among these is the combination of a Western Electric cone-type loud-speaker and a 6025-B amplifier.

To its increased tone-range this amplifier adds the further improvement of much increased output power. Experience has shown many broadcast listeners that the most satisfactory loudness is one much greater than sufficient to "follow" the program. Tests have definitely established the amount of electrical power required at the loud-speaker terminals for various programs, and have also shown the additional load capacity needed in the amplifier to avoid overloading during the loudest passages of music. This knowledge has been embodied in the 6025-B amplifier.

The 6025-B is a single-stage amplifier requiring no power other than that supplied by the commercial 60 cycle 110-120 volt lighting system. It is equipped with two 205-D vacuum tubes, one serving as a rectifier and the other as an amplifier.

Its power amplification when working out of the plate circuit of a small vacuum tube, such as is used in most radio sets, and into an impedance of 4,000 ohms, that of the 540-AW re-



The 6025-B amplifier

ceiver at about 250 cycles, is about 1200 times. It amplifies all the tones of the musical and voice range by practically the same amount, and thus introduces no noticeable distortion of the program.

It is compactly contained in an octagonal metal case with a sloping cover which is modeled on the same lines as the base of the 540-AW receiver and finished in the same dark bronze. The color and attractive design make it a pleasing and unobtrusive object in one's home.

In order to describe its operation a schematic is given in the accompanying figure. A power transformer connects the 110-volt, 60-cycle supply of the electric lighting circuit and

Inside view of amplifier, showing power transformer

the circuits required respectively to light the filaments of the two vacuum tubes and to supply the plate current. The rectifier tube with its plate and grid tied together acts as a one-way valve allowing current to flow only during one-half of the cycle. This rectified current passes through a choke coil which, with the condensers on each side of it, acts as a filter,* reducing the 60-cycle ripple in the rectified current. After passing through one winding of the output transformer and the amplifier vacuum tube, the current flows from the mid-point of the winding of the power coil which supplies filament current through the

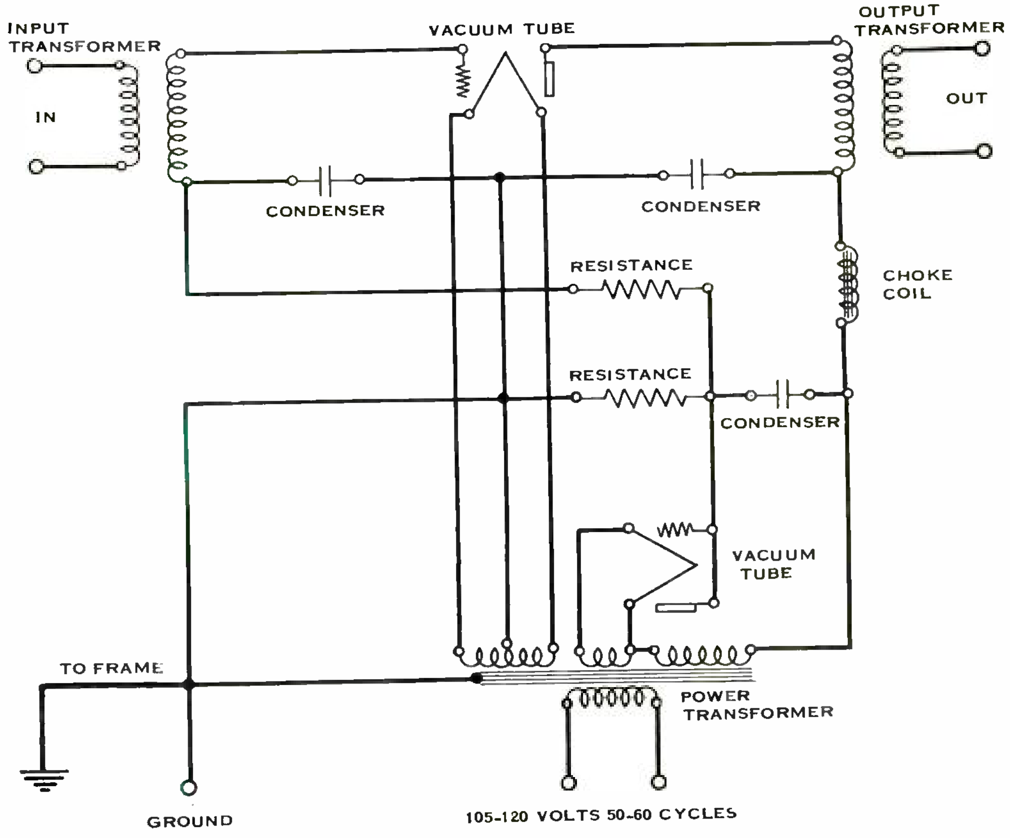
Inside view showing tubes

1000 ohm resistance which produces a fall of potential of about 28 volts. Since the grid of the amplifier tube is connected to the negative end of this resistance the grid is given a corresponding negative bias with respect to the mid-point of the filament. With respect to this point, the voltage of the amplifier-tube plate is about 350; this high voltage is necessary to secure undistorted the output desirable for a large living-room. The volume then amounts to about +20 transmis-

* *The filter may also be viewed as a reservoir which stores energy in its capacities and inductance during one-half of each cycle and releases energy during the other.*

sion units. In the grid circuit there is one-half microfarad. This shunt capacity with the 48,000-ohm series resistance serves to prevent voltage variations across the 1000-ohm resistance from reaching the amplifier-tube grid—an additional precaution against a humming noise due to the 60-cycle power supply. On most power sources this noise should be scarcely perceptible. However, where it occurs it may be reduced in some localities by grounding the terminal marked "G," although in other places the grounding may make the "hum" noticeable. This condition may occur where the radio set is grounded to the same point and the ground connection is not of very low resistance.

With the 6025-B amplifier connected to the Western Electric "cone" (540 or 548 loud-speaking telephone) the best results usually are obtained by connecting the input of the amplifier to the output of the first audio-frequency amplifier of the radio set. If the set is properly designed, sufficient energy can be obtained at this point, except for receiving from very distant stations. Sufficient energy cannot be obtained directly from the detector itself without distortion due to overloading of that tube. If two audio-frequency stages employing transformer coupling are used before the 6025-B amplifier, the quality may be somewhat impaired by frequency-cut-off distortion in the transformers.



Schematic diagram of the 6025-B amplifier

Methods of Measuring Children's Hearing

By Harvey Fletcher

THREE million American school children are partially deaf. It is harder for them to learn, and later on it will be harder for them to earn. If these children were early given medical attention, social and economic loss might be saved. To pick them out, a method of testing is needed, quick enough to survey large groups in a short time, and accurate enough to segregate the deafened ones for further examination.

In a search for such a method, officers of the American Federation of Leagues for the Hard of Hearing have been cooperating with our engineers during two or three years. Some of our proposals looked so promising that the Laboratories were asked to undertake an investigation and the writer was made chairman of a Federation committee for the purpose.

Through the efforts of Dr. Wendell Phillips, organizer of the Federation and also president of the American Medical Association, a conference was arranged between the members of this committee and Dr. William J. O'Shea, Superintendent of Schools of New York City. As a result of this conference, two representatives of the Board of Education, John T. Conroy, M.D., and Harold G. Campbell, and also the Executive Secretary of the New York League for the Hard of Hearing, Miss A. W. Peck, were asked to work with the committee. A simple testing method requiring little or no apparatus was desired and several suggested methods were considered by the committee.

One which at first appeared practicable was based on the fact that about eighty-five per cent. of any group of children chosen at random will have normal hearing. It was proposed that a speaker should pronounce in a whispered voice test numbers to be written down by the children, and that the intensity of the sounds should be varied by changing the distance between the speaker and the listeners. A number which was correctly recognized by only eighty-five per

4-A Audiometer used in measuring children's hearing cent of the children would then be assumed to have had the minimum intensity necessary for audibility by the normal ear. Children in the fifteen per cent. who failed to understand this number would thus be indicated as having less than normal sensitivity of hearing. Although the method was theoretically possible, it proved impracticable even when used by specialists. In the first place, due to the reflection of the sound by walls and floors, the quality of the speech arriving at the ear became much poorer as the distance between the speaker and the listener increased. Also, varying noise conditions which are always encountered in school rooms made it difficult for the children to understand the numbers correctly, even when they were pronounced fairly loudly.

The method which finally proved to be the most successful was that involving the use of the phonograph audiometer, an instrument developed by the cooperative efforts of several engineers in our Laboratories. It consists of a spring-driven turntable like that of an ordinary phonograph, an electromagnetic reproducer, and a group of telephone receivers. Light wooden trays were found to be the most convenient way of storing and

A group of school children having their hearing tested by means of the phonograph audiometer distributing the receivers to the children. Each tray contains eight receivers, wired to jacks through which cord and plug connections are made between trays and to the reproducer.

After the telephone receivers have been distributed and properly adjusted, the children are told that they are about to hear numbers called, first by a woman and then by a man, who seem to be moving farther and farther away, so that the sounds will grow weaker and weaker. They are asked to write as many of these numbers as they can hear. The phonograph is then started, and the first thing they hear is: "You are going to have your hearing tested. Write the numbers which you hear in column 1." Then they hear numbers spoken, the loudness of each sound being less than that of the preceding one. The test is given twice by a woman's voice and then twice by a man's voice. The receivers are then changed to the left ears and the test repeated. In the upper grades, a record of three-digit numbers is used, while for the earlier grades the record is one of two-digit numbers; it has been found impracticable to use this group method for testing in grades below the second half of the second grade. (For younger children the 3-A audiometer was found to permit as convenient and

NAME *John Smith*

AGE *13*

GRADE *6A³*

DATE *Jan. 26, 1926*

DO NOT MAKE ANY NOISE
AS IT WILL SPOIL THE TEST

INSTRUCTIONS

You will hear numbers spoken by a person who is moving away from you. The voice will get weaker and weaker. Listen carefully and write as many numbers as you can

Hearing Loss	1	MASTER SHEET RECORD No. 1 — TEST 1	TEST 2	LEFT EAR 5	6	7	8	Hearing Loss
30	526	526	538	483	853	541	466	30
27	348	348	363	525	436	285	868	27
24	414	414	318	624	841	115	543	24
21	111	111	868	482	218	821	225	21
18	648	648	338	856	414	118	262	18
15	526	526	182	416	483	431	444	15
12	826	826	548	638	441	284	622	12
9	363	363	351	463	18	431	415	9
6	523	528	341	844	298	123	678	6
3	664	634	588		664			3
0	131	124	565		438			0
-3		858	134					-3

He…

Hearing Loss *0*

TEST 3	TEST 4
863	646
224	662
546	648
288	624
883	331
416	462
813	452
345	126
588	831
133	833
461	554
165	636

F 1372 (1-26) 1-162—12105

…ORY

Did you ever … n in your ear? *no* Which Ear? —

When? —

Did you ever … *no* Which Ear? — When? —

Does it run …

Do you ever … ear, like buzzing, hissing or roaring? *Yes* … hen? *In swimming*

Record sheet filled in by child whose hearing has been tested, with master sheet placed upon it for reference. It will be noted that the child has a hearing loss of three transmission units, but anything under nine units is not serious.

rapid a test as any other with which we are familiar.) Master sheets for correcting the papers are so arranged that for easy comparison they may be placed alongside the numbers written on the blank form by the child. The hearing-loss for any test is found in the outside columns opposite the last number heard correctly.

With the apparatus and method outlined above, it was found that there could be tested per hour 75 to 150 children, depending upon the degree of efficiency in organizing them into groups of forty and getting them to and from the class room provided for the tests. Of over 4000 school children thus tested by J. B. Kelly of our Laboratories and his assistants, it was found that 595, or 14.4 per cent, were hard of hearing, 3.2 per cent had defects in both ears, and 11.2 per cent had defects in one ear only.

Finding it inpracticable to make a careful otological examination of all the 595 deafened children, Dr. E. P. Fowler * chose fifty-seven from one school as being representative of what would be found in the others. Using our 2-A audiometer careful audiograms were made for all of these deafened children; these audiograms served as the principal data for making his clinical diagnosis. In every case but one of the fifty-seven selected by the phonograph audiometer test, Dr. Fowler found definite ear troubles such as running ears, catarrhal deafness, nerve deafness, adhesions and congestions of the ear drum, and results of mastoid operations. In one case a bead was found lodged against the ear drum.

On examining the school records, it was found that these fifty-seven deafened children had repeated sixty-six classes, while the same number of children having normal hearing, selected at random in the same grades, had repeated only eighteen classes. These figures are striking, and indicate that if proper methods of finding deafened children and treating them both medically and educationally are adopted by the schools, probably more money will be saved by preventing the children from repeating classes than will be used in finding and treating these deficient children.

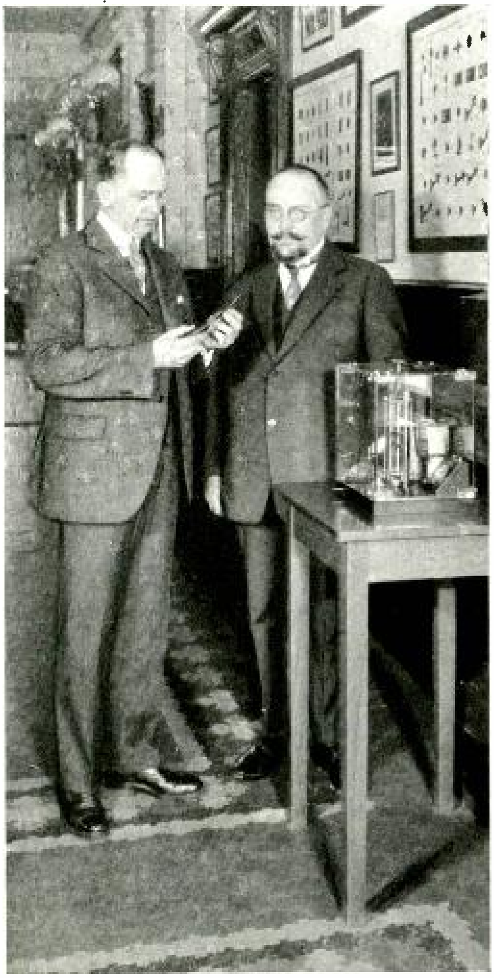
Apparatus and technique having been made available for locating these cases, the responsibility is now that of educational authorities to put them to use and to make the detection, care and education of such children a matter of school routine. The League for the Hard of Hearing is striving to interest the nation in this vital matter. It behooves all physicians, and especially otologists, to do their part, taking the leadership in this hitherto neglected work. It is with a feeling of pride that the Bell Telephone Laboratories, the real successor of Alexander Graham Bell's first simple laboratory, can point to the major part it has played in this important work for the conservation of hearing, a matter which was always uppermost in the mind of Dr. Bell.

* *Of the Manhattan Eye, Ear and Throat Hospital and joint author with Dr. Fletcher of a paper recently presented before the American Medical Association.*

In the Month's News

FRANK B. JEWETT will speak at the Purdue University Commencement on June 15th.

ON MAY 15th Mr. Craft addressed the post-graduate school of the Naval Academy on "Research and Engineering." To take him to Annapolis, a Navy airplane called for him at Sea View, New Jersey, where he was attending a conference of vice-presidents of Bell System Companies. The flight was made in a little less than two hours.



Dr. Karl W. Wagner, with S. P. Grace, examines a section of permalloy cable

A. M. GRANICH spoke on "Electric Filters and Their Application in the Telephone Art" at the April 12th meeting of the C. C. N. Y. branch of the American Institute of Electrical Engineers.

PROFESSOR K. T. COMPSTON, of Princeton, was the guest of the Colloquium at the May 17th meeting. He spoke on "The Study of Electric Discharges in Gases by the Method of the Exploring Electrode."

A RECENT VISITOR to the Laboratories was Karl Willy Wagner, Ph.D., Dr. Eng. h.c., distinguished German scientist and engineer. Dr. Wagner is president of the Office of Engineering and Research in the Administration of Posts, Telegraphs and Telephones.

BROADCASTING ACTIVITIES carried on by the Radio Broadcasting Department of the American Telephone and Telegraph Company, under the call letters WEAF, have been incorporated as the "Broadcasting Company of America." An ever-widening scope of interests and the differences existing between radio and telephone problems have made a separate organization advisable. The new company is owned by the American Telephone and Telegraph Company and its personnel remains practically the same. WEAF's policies of broadcasting development and technique will

Standing: C. J. Davisson and W. Wilson. Seated: K. K. Darrow and Professor Compton

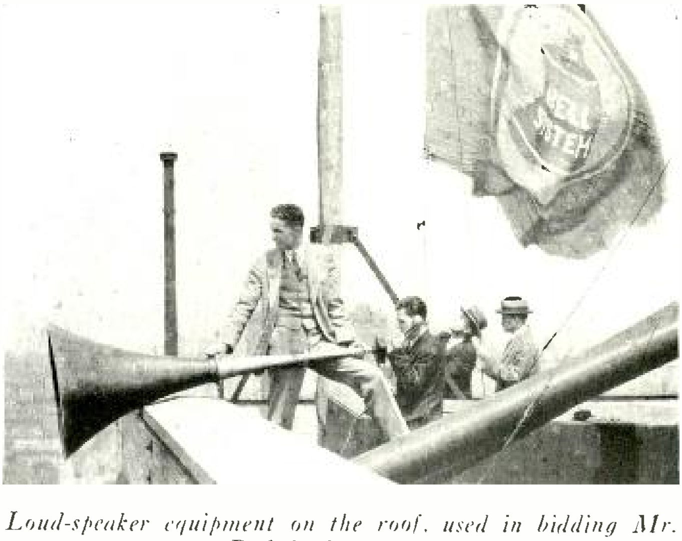
be followed in detail. Among the officers of the company are: President, J. C. Lynch; vice-president, W. E. Harkness; manager of broadcasting, G. F. McClelland.

A GRADUATE of the Student Assistant Course who felt the need of further education and took leave of the Laboratories to attend the University of Wisconsin is J. Raymond Erickson. He is now in his junior year, and in a recent letter says:

"The past few months found me very busy, indeed, with both studies and outside activities. First, I tried my hand as Contributing Editor and then as Business Manager of one of the newer magazines on the campus. That was a lot of work, but it gave me some good experience and brought me in contact with many interesting people about town. The indoor track season, during which I won my letter, is now ended, and I am resting up until our outdoor campaign opens. Last week I was informed that I had been elected to Eta Kappa Nu, the honorary electrical fraternity.

"My work at Wisconsin is progressing smoothly. The value of the Student Course and the work at West Street is being impressed upon me more each day. The RECORD comes every month and it is a real pleasure to read of the doings of the "gang."

A LABORATORIES SEND-OFF was accorded Charles G. DuBois, President of Western Electric and Director of Bell Telephone Laboratories, when he sailed for Europe on April 27th. As the steamer passed our building, the Bell System flag was dipped three times and wishes for a pleasant voyage were sent over by Mr. Craft



Loud-speaker equipment on the roof, used in bidding Mr. Dubois bon voyage through a public address system in one of the laboratories and a sound projector on the roof. Musical numbers preceded and followed Mr. Craft's greeting. The group assisting on the roof included G. C. Jones in charge of the projector and C. T. Boyles at the flag halyards. The pick-up and amplifying end was handled by D. G. Blattner and H. F. Hopkins.

FIELD INSPECTION ENGINEERING WORK in Western Pennsylvania will hereafter be handled from the Philadelphia Headquarters; E. A. Whelan, who has been acting as Local Engineer at Pittsburgh, has been assigned to duties in the Complaint Bureau at West Street. J. M. Schaefer has completed his temporary assignment at West Street and has returned to Field duty in the Central Territory, with headquarters at Hawthorne. R. J. Nossaman, who has been acting as Local Engineer in the Western Territory, has been transferred to duties in the Central Territory, with headquarters at Hawthorne. P. B. Almquist, who has been assisting Mr. Nossaman at San Francisco, has been appointed Local Engineer for the Western Territory.

During April, D. A. Quarles, W. A. Boyd, H. G. Eddy and W. C. Miller of the Inspection Department were in Hawthorne on regular Survey Conference work. R. H. Hart was in Pittsburgh in connection with the Inspection Survey of Iron and Steel products. C. H. Amadon recently spent several days in the Southern Timber District making a survey in connection with the supply of timber products. W. A. Shewhart attended the April meetings of the American Physical Society and of the National Academy of Sciences in Washington.

Vail Medal Awards

Five silver medals have been awarded to men and women of the Bell System "in recognition of unusual acts or services which conspicuously illustrate the high ideals which governed the policy of Mr. Vail as to public services." One man saved the life of a fellow-lineman who had come in contact with a high-tension wire; a lineman and an operator each maintained service during floods; operators in two small towns warned the police and summoned aid when bandits attempted to rob neighboring banks. All of these acts were in the face of danger and some in addition involved great hardship.

The five medallists were selected from sixty-one persons to whom bronze medals were awarded by the associated companies of the Bell System.

Beginning with the current year men and women of Bell Telephone Laboratories will be eligible for Vail Medals. Consideration will be given first by a Committee of Award, consisting of our Board of Directors; J. W. Farrell has been appointed its permanent secretary. Acts of those to whom it awards bronze medals will be considered by the national committee for further recognition.

Organizing Our Researches

By Harold D. Arnold
Director of Research

THE fundamental duties of the Research Department are to obtain new scientific knowledge which may serve our art, and to consider ways in which this information may be utilized. Of its output, inventions are a valuable part, but invention is not to be scheduled nor coerced: it follows research through the operation of genius; and the best that any department can do to promote it is to provide a suitable environment. In these types of activity the Research Department has no monopoly, for they are common to all engineering. Whatever peculiarity it has is determined largely by the nature of the sources from which it must draw its information. Special methods and facilities required in this search lend color to the organization and operation of the department.

There is a vast body of fact and experience which is the stock-in-trade of the engineering profession. This is by no means completely organized, and in many cases the resources of one specialized field are imperfectly appreciated in another; but to effect the necessary coordination and interpretation in improved instruments and methods is the province of engineering as distinct from research.

There is, however, a great mass of scientific information which has not yet won an accepted place in the equipment of engineers either because its field of application is narrow or because its possibilities have not been sought out with an eye to engineering utility. There is, furthermore, and most important of all, that enormous body of knowledge which the world will have in the coming years, but of which we are now entirely ignorant. To these two sources the Research Department addresses itself. On the one hand through the search of scientific literature, and through personal contact with the world's specialists, it attempts to learn and to employ information which has so far been imperfectly brought to bear upon engineering projects; and on the other hand it searches out by experimentation facts and relationships which have never before been recognized.

For the first activity it is important to understand so thoroughly the language of science that an evolving thought may be grasped, and its bearing upon our industry appreciated, even though the author may present it in inadequate or incomplete form. For this are required men whose excellence in each of the directly allied sciences as taught in the schools is such as to establish them as recognized masters; whose opportunities with us are such as to maintain their constant contact with the vital growth of their sciences, and whose experience is such as to make them quick to vision the embodiment of new ideas in engineering form.

When we go beyond this and plan

to find new facts of Nature we must approach with even more care and circumspection, for she indeed "speaks a various language," and her response can only be obtained by those who devote themselves patiently and with the utmost skill to her pursuit. She reveals herself most readily and understandably through the medium of ingenious and precise experiments, and for these experiments diverse and often complicated facilities are required. So for the pursuit of new knowledge the Research Department must equip itself with facilities which often little resemble the ordinary tools of our industry, and must seek continually new and more ingenious devices by which to compel Nature's secrets. Only a part of its equipment can be of standardized form, for few things are standardized until their engineering worth is established, and by that time, for the most part, they have left the field of research. Its laboratories are always workshops in which as investigation presents daily new aspects for attack the worker must develop new tools and methods.

It is not, however, so much the nature of the facilities as their diversity which is most impressive. Our research problems are scattered along the whole frontier of the sciences which contribute to our interests, and extend through the fields of physical and organic chemistry, of metallurgy, of magnetism, of electrical conduction, of radiation, of electronics, of acoustics, of phonetics, of optics, of mathematics, of mechanics, and even of physiology, of psychology, and of meteorology. In each field inquiry carries the important question of its practical applications and thus involves consideration of the specific devices which our industry uses and study of new forms into which they may be molded and new services which they may be made to render.

With a field so varied, and with the unknown always facing it, the Department has many of the characteristics which go with frontiering. We try, as experience may give us confidence, to keep the general march of progress along lines where advance is most desirable and seems least difficult. But at every point in the front the actual winning of new ground comes from the effort of the individual who by his own persistence, ingenuity, and ability, finds ways to push the boundary forward; and often from the vantage ground thus gained we must reform our line of attack. Compared with this procedure the more usual engineering methods are like those great operations which follow the frontier, when cities are built, lines of communication are established, and all the means of human comfort and civilization are developed and multiplied through the coordination of wealth and labor to the execution of plans which are prepared in accordance with standardized principles and are administered with an eye to economic considerations. By comparison the work at the frontier may be sketchy in appearance, and may seem at times futile and discouraging, but it must be remembered that it is only along the avenues which investigation has opened that organized engineering can extend its lines of fresh growth.

Try as we may, and as we ought, to maintain an even and considered front in our attack on the boundaries of knowledge, there are always some salients which will yield only to siege or to extended flanking operations. So we find in the department men who are patiently and cunningly attacking old problems,—problems which it might seem we had passed in our rapid progress, but which have still remained unconquered, and are frequently key positions of the greatest value. Compensating for these long established sieges are slender lines of adventure which have been thrust forward into the unknown far beyond any present hope of consolidation. In this virgin territory we find men, whose success must depend largely upon their own initiative and resourcefulness, striving for some point which may bring with its winning the conquest of new and broad regions.

With problems and facilities so diverse, but with specialists chosen for each field, the administrative function of the Research Department resolves itself chiefly into the maintenance of facilities and the coordination and distribution of information in such a way that each man may take to his own problem the most adequate means of solution and may at all times be in touch with progress at other points. It would be deadly to standardize too rigidly this administrative assistance. It can, however, be coordinated in such a way as to produce real economy of operation if in its giving there is always the keenest appreciation of the specific needs of the individual investigator and if the line of supplies and service is kept in personal touch with him as he advances. Organization lines within the department are therefore arranged with a view to the distribution af advice and information, the rendering of helpful service, and the consolidation and use of new knowledge as it is obtained.

All the various elements which go to make organized research a success, may be grouped, if we allow ourselves great latitude of interpretation, under the terms: experience, facilities and enthusiasm. Of these, the first two are subject to plan and provision; and the breadth of success may be greater the more liberal their providing. We must never forget, however, the strides which have been taken by men with small training and meagre means, but possessed with a driving spirit for research. Such great enthusiasm may indeed win through with imperfect experience and facilities; but the latter, no matter how perfect, are dead and worthless without an animating spirit. No organization or method of administration can create the vital spark of the investigator. It is born in the fibre of the individual. It can, however, be encouraged to expression; and working in contact with like spirits it gains an associated strength that is indomitable.

The Research Department, then, to fulfill its fundamental duties, is organized and administered with a view to fostering the spirit of research in its individual investigators, to associating them so that individual and group experience may find its most useful expression, and to providing the best possible facilities for the materialization of their ideas. Beyond this the department moves in its interdepartmental relations and in its general routines just as do the other units of Bell Telephone Laboratories.

The Research Department

By Paul B. Findley,
Managing Editor

In previous articles of this series an attempt has been made to trace the flow of ideas through two departments of the Laboratories which deal principally with telephonic devices in the concrete. A survey of the activities of the Research Department shows in contrast that here ideas tend more to the abstract, that the effort is to find and formulate broadly the laws of nature, and to be concerned with apparatus only insofar as it serves to determine these laws or to illustrate their application in the service of the Bell System. Once a feat has been performed, and its commercial possibilities demonstrated, the problem of producing the apparatus and of incorporating it into the telephone plant or of utilizing proposed systems becomes one for the Development Departments.

To those sectors of the frontier of knowledge in which we are most interested, there are nine main avenues of approach. These are through studies of speech, hearing, conversion of energy between acoustic and electric systems, electric transmission of intelligence, magnetism, electronic physics, electromagnetic radiation, optics, and chemistry. Work along these lines is headed by members of the staff of Harold D. Arnold, Director of Research, who with their co-workers comprise some five hundred * people.

* *Not including the hundred-odd manufacturing workers and their supervisors in the Tube Shop.*

The conversion of energy between acoustic and electric systems is a fundamental problem of our Bell System, involving as it does the pick-up of sound waves by a transmitter diaphragm and the production of corresponding electric waves; and at the other end of the line the conversion of electric waves into motion of a receiver diaphragm and the production of sound waves in air. Because it is so fundamental, the problem has been attacked from several angles by many investigators in different Research groups. To one group, however, is entrusted a continuous program of research with especial emphasis on the instruments furnished to the Associated Companies.

This group is in charge of Halsey A. Frederick, who entered the Laboratories in 1912. His first work was on mechanical repeaters; in this connection, working with R. L. Jones, he was the first to use present-day methods of impedance analysis of receivers and related apparatus. The war period saw Mr. Frederick interested in submarine signalling, sound ranging, and aircraft detection. A problem in line with his general transmitter and receiver work is the adapting of these instruments to such special uses as the audiometer and audiphone. In recent years his group has carried the development of the carbon-button microphone to a point where it is recognized as the standard for broadcasting and voice reinforcement. It has also developed the electrical stethoscope used in the study of the heart, and is now attacking the question of mechanical oscillators and relays for voice-frequency signalling systems. Mr. Frederick holds from Princeton the degrees of B.S. and E.E.

A group reporting to Irving B. Crandall * specializes in the field of speech and certain other phases of sound phenomena. Mr. Crandall holds degrees of A.B. (Wisconsin) and Ph.D. (Princeton). His first assignment on entering the Laboratories in 1913 was a study of the flutter effect in long loaded lines, following the pioneer investigations of John Mills. A year later Mr. Crandall made the first study of telephone quality, for which he and his group developed precision instruments and technique; among the former being the air-damped condenser transmitter and a high-quality telephone system. Here were made the first attempts at precision measurements of hearing and the first investigation of the limits of frequency and energy in speech. During the war the efforts of this group were largely devoted to the investigation of devices for underwater sound transmission and detection. Later studies were one of speech through extensive oscillograms, and one of sound radiation leading to high-quality loud speakers. Recently this group has been interested in architectural acoustics and particularly in methods for the sound-proofing of the new acoustic laboratories in Section H.

The electrical transmission of intelligence begins, of course, with the output of the transmitter, telegraph key, or photo-electric cell. In this vast field two landmarks are the techniques, respectively, of filter networks, and of carrier-currents. Ralph V. L. Hartley, who heads this work, entered the Laboratories in 1913, having just returned from three years as a Rhodes Scholar at Oxford. He took part in the Bell System's early radio development, and has many fundamental inventions to his credit. During the war he was concerned with binaural methods of sound-location, for which he developed certain laws. Later his research work turned to carrier currents, telephone repeaters,

Halsey A. Frederick

and other aspects of transmission. These investigations are continued by three groups under his supervision.

Of these, the group reporting to R. C. Mathes carries on fundamental studies in voice transmission and telegraphy, including the development of voice-controlled relays. This group is regularly consulted by Systems en-

* *A picture of Mr. Crandall may be found on p 15, of the* Record *for March, 1926.*

gineers on the transmission features of proposed circuits. J. W. Horton's group is concerned with carrier transmission for telephony, telegraphy and wire-broadcasting. As an adjunct,

Ralph V. L. Hartley

they have applied much thought to methods of generating carrier currents and of measuring their frequencies. They carry on a continuous study of vacuum tubes as circuit elements, and of the modulating effect of magnetic-core materials. This group was also responsible for the electrical methods of the picture-transmission system. K. S. Johnson and his group make basic theoretical studies of networks and design special forms of filters, attenuation-equalizers and phase-shifting networks for the use of other departments. Studies of subscribers' and other telephone stations also are made in this group.

The closely-allied fields of vacuum tubes and radio are supervised by William Wilson.* In 1914 Mr. Wilson entered the Laboratories with a background of undergraduate study at the University of Manchester, and five years' graduate research at Manchester and Cambridge. From his Alma Mater he holds the degree of Doctor of Science. His early work was a study of electron emission from oxide-coated filaments. Following his participation in the Arlington radio-telephone tests in 1915**, he was placed in charge of research development and manufacture of tube filaments; during the war he directed the entire Tube Shop. At the war's end, supervision of tube research was added, and within recent months the direction of radio research.

Fundamental investigations in electronics, especially as related to vacuum tubes, are studied by C. J. Davisson and his group. Development, design and manufacture of vacuum tubes is directed by M. J. Kelly. A description of the Tube Shop appears elsewhere in this issue.

Radio research activities are carried on by groups reporting to four men. R. A. Heising has charge of certain radio investigations, including the fundamentals of oscillator design and short-wave transmission problems; C. R. Englund and H. T. Friis of field strength and "static" measurements, and other phenomena of radio reception. A. A. Oswald, who designed the transatlantic radio-telephone transmitter at Rocky Point, is now at Rugby, collaborating with British engineers on the transmitting installation there. J. C. Schelleng is in charge of the United States end of the same project, and also of a group who are

* Bell Laboratories Record, *Jan.*, 1926, *p.* 222.

** Bell Laboratories Record, *October*, 1925, *p.* 44.

investigating short-wave transmission and the properties of antennas.

A number of special types of transmitters and complex conversion units of other forms have been developed under the supervision of Joseph P. Maxfield.* Among the latter may be mentioned the phonograph recorder and reproducer. Mr. Maxfield was graduated in 1910 by Massachusetts Institute of Technology. When he entered the Laboratories in 1914, a fundamental study of carbon microphone contacts was his first work. During the war he engaged in the development of devices for airplane detection and sound ranging of enemy guns. From 1919 on, Mr. Maxfield has concerned himself with loud-speaking systems and allied problems. His contributions have been to the art of voice reinforcement and to the early development of the high-quality stretched-diaphragm carbon microphone. In recent years the researches of this group in sound recording and reproducing have culminated in a system used commercially for the production of records**, the Orthophonic Victrola *** and the talking motion pictures which employ synchronized long-running phonograph records.

Magnetism is another subject fundamental to electrical communication; it enters into nearly every device which converts electrical energy into mechanical. A striking recent application of magnetic materials in another field is that of permalloy to the continuous loading of transoceanic cables. Development of various new magnetic materials and some of their special applications are included among the research problems directed by Oliver E. Buckley.*

His introduction to practical telephony came to Mr. Buckley during high-school years when he had charge of a small automatic system serving his home town in Iowa. After being graduated from Grinnell College in 1909, and receiving the degree of Doctor of Philosophy from Cornell in 1914, he entered the Laboratories in the latter year. During the next three years he worked on the production and measurement of high vacua; the ionization manometer is one of his contributions to the latter art. On his return from overseas service, where he was a major in the Signal Corps, he took up his present work.

Harvey Fletcher

Six group heads report to Mr. Buckley. Gustaf W. Elmen, inventor

* Bell Laboratories Record, *Nov.*, 1925, *p.* 96.
** Bell Laboratories Record, *Jan.*, 1926, *p.* 197.
*** Bell Laboratories Record, *Nov.*, 1925, p. 95.

* Bell Laboratories Record, *Sept.*, 1925, *p.* 27.

of permalloy, continues to develop new magnetic materials and to find new fields for their application. Louis W. McKeehan conducts researches in ferromagnetism and X-Ray crystal analyses, through which he has worked out an explanation of the properties of permalloy. John G. Gilbert has charge of loaded submarine cable development; he has contributed many features of the New York-Azores cable project and has done much of the engineering in connection with its loading. Allison A. Clokey has developed terminal apparatus for submarine cables; in his group has been done all the engineering of the new multiplex system now being installed on the Azores cable. John B. Johnson, well-known for his cathode-ray oscillograph, is engaged in special vacuum-tube studies. F. S. Goucher, who withdrew from the Laboratories during the war to serve in the British army, has recently returned; he will carry on a study of the microphonic properties of carbon.

Herbert E. Ives

Mathematical assistance to all departments of the Laboratories is furnished by Thornton C. Fry * and his group. Mr. Fry came to the Laboratories in 1916 from the University of Wisconsin, where for the previous four years he had been an instructor in mathematics and had received his Ph.D. An account of the work of his group may be found in the RECORD for September, 1925.

Studies of hearing, especially in relation to telephone transmission, were begun by Harvey Fletcher soon after he entered the Laboratories in 1916. Intelligibility of speech is affected by loudness, by elimination of any part of the normal frequency range, and by noise; these factors are of great importance in the design of many parts of the telephone plant. Mr. Fletcher's group is also concerned with tests for receivers and transmitters. Their basic studies have led to the development of laboratory tests which depend upon the electrical quantities rather than on human speech and hearing. Mr. Fletcher and members of his group have made a broad study of the human ear, and in particular of individual variations in hearing-sensitivity. The audiometer, now coming into general use by otologists, grew out of this work, as well as the audiphone to aid those of impaired hearing. Another device of popular interest which originated in this group is the artificial larnyx. A current activity is the development as a standard of reference of a telephone transmission system calibrated

* BELL LABORATORIES RECORD, *Sept.*, 1925, *p.* 17.

in absolute units. This system may be used to measure the efficiency of other telephone systems.

Mr. Fletcher was graduated by Brigham Young University, to which he returned as an instructor after graduate study at Chicago. He holds the degree of Doctor of Philosophy from the latter institution.

Ten years of research into light and color phenomena preceded Herbert E. Ives' entrance into the Laboratories in 1918. Among his activities in these years was the development of airplane photography for the Signal Corps. His first investigation in the Laboratories was into electrical contacts, a work in which his group is still interested. Of recent years he has conducted researches into electrical transmission of pictures; he was in general charge of the development which led up to the first commercial demonstrations in 1924. The photoelectric cell, which plays so important a part in this apparatus, is still under investigation, as well as electron-discharge tubes for use in protection of telephone lines and apparatus against high voltages. Mr. Ives holds the degrees of B.S. (Pennsylvania) and Ph.D. (Johns Hopkins); he is a past president of the Optical Society of America.

In 1906 our Chemical Research organization was formed by the consolidation of groups from Boston and Hawthorne, with one already existing here at West Street. Its head for eighteen years was J. W. Harris*; since his death in December, 1924, the work has been directed by Robert R. Williams. After graduation by the University of Chicago, and after various governmental and industrial connections, Mr. Williams entered the Laboratories in 1919. His department is organized in three groups under the direction of C. D. Hocker, J. E. Harris and H. H. Lowry.

Robert R. Williams

Current chemical-engineering problems are handled by C. D. Hocker, who also is doing research on insulating enamels, wood preservation and corrosion of cable sheaths. His group makes analyses of both routine and research nature, and evaluation of various materials. Methods of testing finishes* and of analyzing new materials are developed by this group. J. E. Harris heads the group on metallurgical research, including materials for alloys for cable sheaths.

* *To Mr. Harris were due not only the development of the Department as a whole, but many individual contributions. Of these, the commercial use of enamel insulation, and the lead-antimony sheath for telephone cables are especially noteworthy.*

* *An account of the correlation between accelerated life tests and actual service is contained in the* RECORD *for March, 1926, in an article by E. M. Honan, formerly of this group.*

He is also interested in the preparation of magnetic materials and development of filaments for vacuum tubes. H. H. Lowry is concerned with the development of microphone carbon

Richard H. Wilson

and the study of insulating materials, such as paper, textiles, and impregnating substances. He is also studying the relation between chemical constitution and insulating properties.

If we may characterize research as a voyage of discovery, we may assuredly think of laboratory service as the favoring wind that smoothly speeds it to success. Service in the Research Department is handled by a group reporting to Richard H. Wilson, who is a graduate of Victoria University, England. After a year as an instructor, Mr. Wilson entered the Laboratories in 1914. His career began in radio research. he helped to build the first receiving set used at West Street. In 1919 Mr. Wilson was transferred to the service group, which at that time had a personnel of five or six people as compared to the hundred-odd of today. The problems handled by this group vary from the question of power supply to keeping track of the departmental expenditures.

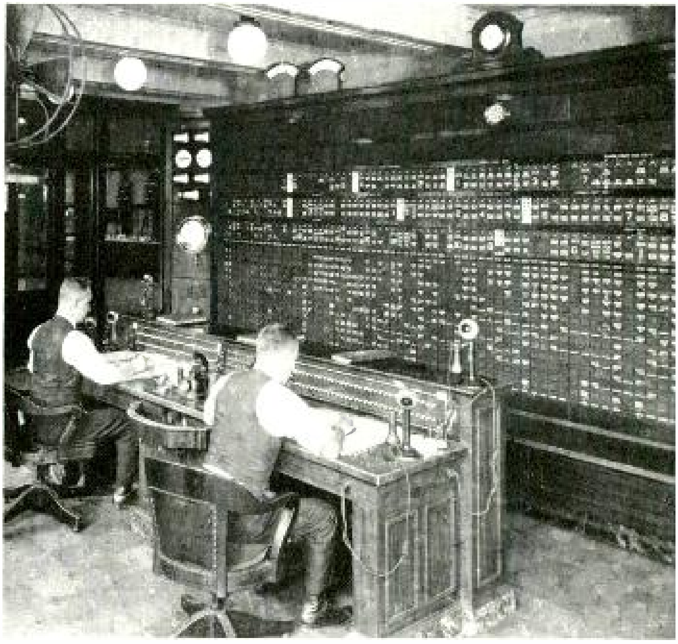
Mr. Wilson has reporting to him four men who handle the various phases of the work. R. O. Mercner and his group collaborate with the research men in designing and having constructed the special pieces of apparatus required for their work. Financial and administrative service is supervised by E. G. Conover. The five departmental storerooms and other services are handled by J. J. Fennelly. With W. A. Mueller is responsibility for the upkeep of laboratory equipment.

Such is the organization of the Research Department. Its input of ideas comes from discovery and study of Nature's laws; its output goes to its sister departments, or directly into the public service through scientific papers of its members. The range of its interests is indicative of the variety of ways in which nature is being brought into service to mankind through the telephone.

Remote Control of Power Station

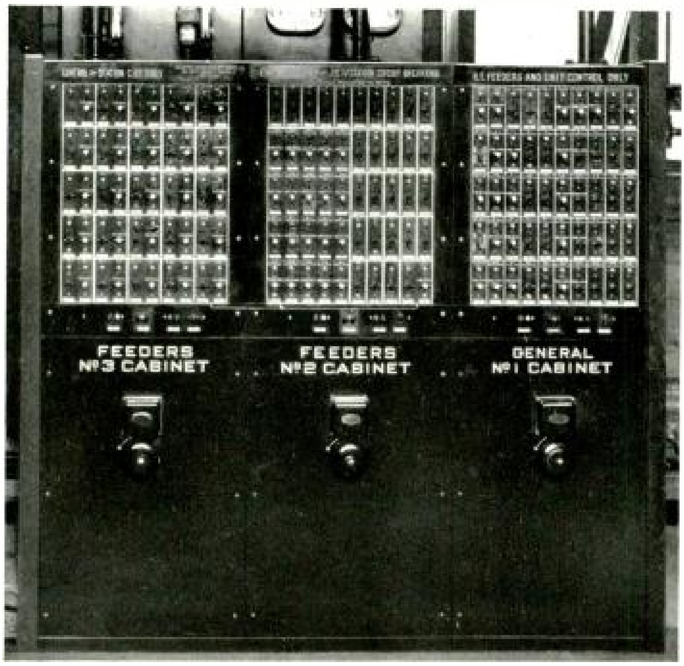
By F. Zogbaum

As networks for the distribution of electric power have developed in size and complexity, a need has grown for automatic and remotely controlled switching. The power station of the small town, with its switchboard at one side of the generator room, was adequately served with automatic circuit breakers for overload protection, and hand-operated switches for the few simple operations of grouping generators and feeders. Modern practice, which ties local power systems into great networks with a few large generating stations, requires a multitude of switches, so that portions of the plant may be isolated and service maintained by spare units and alternative routes. These switches were originally controlled by substation attendants, working under the orders of a load dispatcher or system operator. Directing operations at distant points is hampered by inevitable delays while orders are being executed and reported back verbally to the system operator. Complicated manual switching operations are exposed to human error—a hazard of serious proportions when an enormous amount of power may be misdirected with disastrous results. The public demand for uninterrupted service and the constantly growing market for electric power, increasing the number of substations as well as the pay roll, are all knotty problems facing the operating officials. One answer, of course, is the use of some sort of centralized control with supervisory signals, and automatic substations.



System Operator's Office — New York Edison Company. The Board in the background indicates by lamps the position of switches on all mportant circuits

The problems of indicating at a central point the condition of apparatus at a remote location is one which arose many years ago in the early development of the telephone industry. Methods of signalling between operators and between subscribers and operators are after all nothing more than remote indications of the position of certain pieces of apparatus. A typical case is the lighting of the line lamp when the subscriber's receiver is raised from the hook.* Remote control of apparatus has been carried to its highest point in the machine-switching system, where a subscriber through his dial controls the operation of hundreds of switches. With these things in mind it was only natural that the power companies should look to telephone engineers to help them in their quest for a supervisory system for power networks. The first supervisory system was worked out in the Laboratories to indicate automatically at a central station the position — closed or open — of a number of power switches located at a distant station. The position of the power switch is communicated to the load dispatchers at the central station by causing the illumination of one or the other of a pair of switchboard lamps. One lamp is equipped with a red glass cap and the other with a green cap. Therefore, the attendant at the indicating station, by observing which lamp is lighted, is informed of the position of any given power switch. In practice the red lamp indicates that the switch is closed while the green lamp shows that the switch is open.



Panels at East 39th Street Substation of New York Edison Company to control and supervise all operations and read the percentage load of the East 41st Street automatic substation

A system of this type, of capacity for indicating 200 switches, was installed by the Western Electric Company for the New York Edison Company. The sending equipment was situated at the 201st Street Station of the United Electric Light and Power Company and the receiving equipment at the Waterside Station of the New York Edison Company at East 38th Street, New York City. The connecting lines of this system consisted of two pairs of telephone wires leased from the New York Telephone Company. The system went into use some years ago

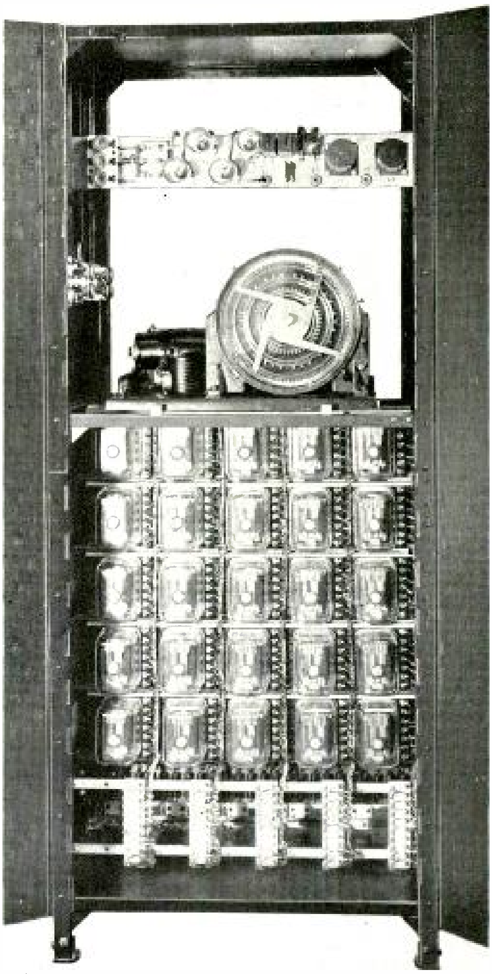
*"Telephone Signalling," in the Bell Laboratories RECORD, January and February, 1926.

This early system gave excellent service for several years; but as its heart consisted of a multitude of relays its action was necessarily slow, and it was finally replaced by a later development which is known as the distributor system.

In recent years the development of supervisory control systems has been rapid, and an excellent combination of control and indication has been effected. There are at present systems of two general types, one using train-dispatching selectors and motor-driven selector keys and the other using modified printing-telegraph distributors and polarized relays. In either case the indications are visual and are produced by individual pairs of telephone switchboard lamps accompanied by group pilot lamps and an alarm bell.

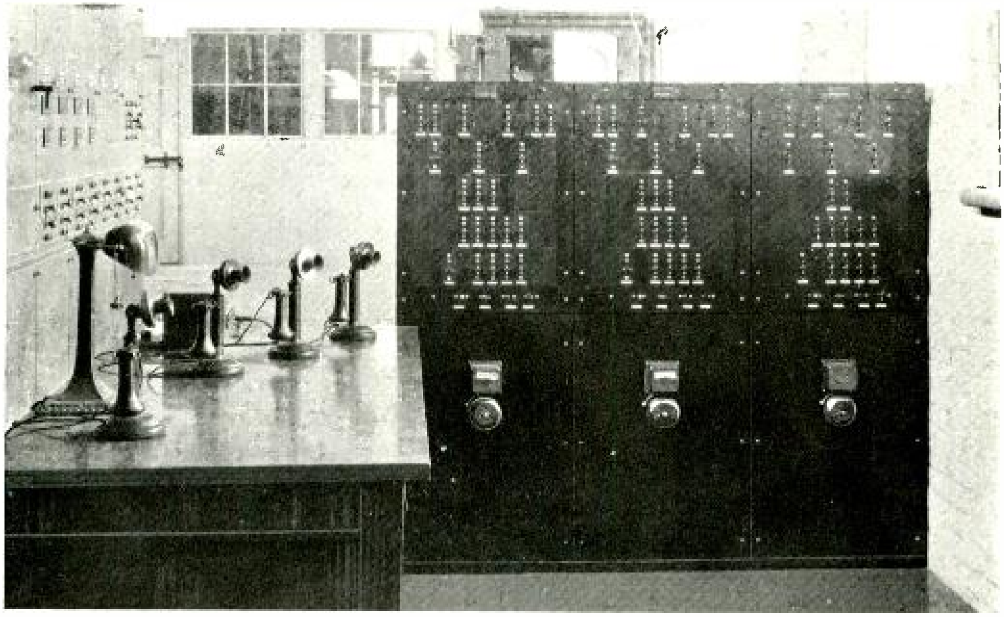
Where either system is used for indication only, the load dispatcher is merely advised of the automatic functioning or manual operation of equipment in the distant stations. In supervisory systems used for both control and indication, the load-dispatcher may by the manipulation of keys operate the equipment in the distant stations and receive instant indication that these operations have taken place. Both systems are designed to operate on extremely small currents; this is particularly true of the currents transmitted over the connecting lines, since these lines are in every case standard telephone or telegraph conductors.

In the distributor system any sending device—switch or control key—and its associated relay at the distant end are given access to the line at the same instant. This is done by a pair of rotating switches in which brush arms travel continuously over a large number of segments. One of these rotating switches, or distributors, is located at the dispatcher's station, while the other is located at the distant station; four wires form the connecting link. The distributors are driven by small direct-current motors regulated to approximately the same speed by individual governors. Exact synchronism of the brush arms is established periodically by a circuit which halts whichever arm is in the



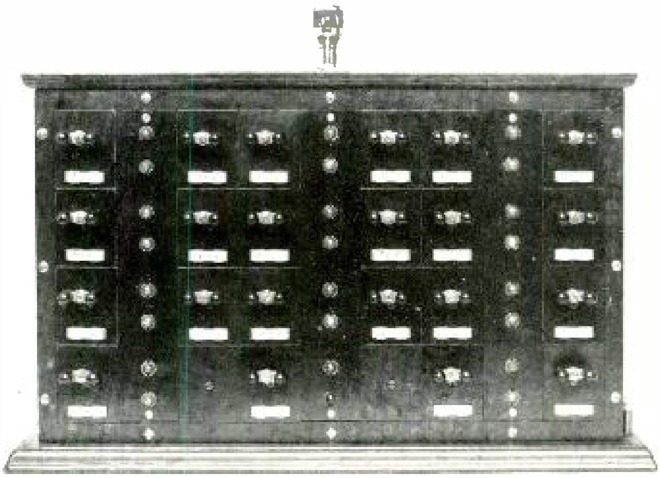
A typical distributor and relay assembly for either end of the system lead until the other arm overtakes it. To a certain segment of the distributor at the distant station are connected two auxiliary contacts of a power switch; to the corresponding segment of the distributor at the dispatcher's station is connected a two-position polarized relay. The polarity of the sending-end segment depends on which of the two contacts of the power-switch is closed, and is thus an indication of the position of that switch as closed or open. Since the pair of distributors rotate in step, the polarities of the segments of the distributor at one station will be transmitted in progression over the connecting lines to the relays at the other station. These relays will operate or not operate, in accordance with the polarity of the current received, and will cause the indicating lamps to change or remain the same, thus reporting whether the switch has changed its position or not.

Likewise, at the dispatcher's station certain segments of the distributor are connected to control keys and at the distant station the corresponding segments are connected to polarized relays which control power switches. When the dispatcher wishes to close or open a switch, he turns the proper key; as soon as the distributors next connect that key with its associated relay, the latter will be operated and in turn operate the switch. Immediately the new position of the switch is signalled back to the dispatcher by a change in the indicating lamps.



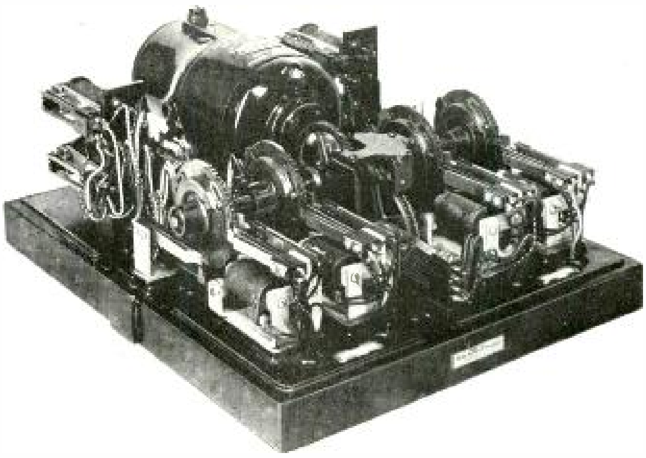
Load Dispatcher's Office, Malden Electric Company. At the right are three panels for the control and indication of all feeders in three distant substations by the selector system

The selector system, on the other hand, utilizes principles and apparatus used in the Western Electric train-dispatching system. For each signal a set of impulses is transmitted which causes a particular selector to close its contacts and thereby operate a power switch or change a lamp-indication. Hand-operated selector keys are used by the dispatcher for controlling switches at the distant station, and a motor-driven selector key is used for sending back from the distant station indications of switch operation. After a switch has been operated by a control circuit or by automatic relays the motor-driven key is started up and sends out a predetermined code of impulses. This series of impulses is transmitted over the connecting lines to the selectors, operating one of them to close its contact points and change the illumination of the indicating lamp. To check up the position of each switch the dispatcher operates a key, which causes the distant motor-driven key to start and thus report the position of each switch.



Dispatcher's control and indicating panel for the selector system

Supervisory control systems are not confined merely to the control and indication of remotely located circuit breakers. In many cases they are used for complete supervision of the functioning of automatic power substations, including voltage regulation, starting and stopping motor-generators, converters and water wheels, and indicating the load of any station and gate opening and water level at distant hydro stations.



Selector system: Motor key for indicating the position of four switches

A system for both control and indication was installed on the lines of the Malden (Massachusetts) Electric Co., in the late summer of 1922. Other systems of both types have been put in operation on the lines of such companies as the New York Edison Company, the Edison Electric Illuminating Co., of Boston, the Detroit Edison Company, the Chicago, South Shore and South Bend Railway Company, the Kansas City Power and Light Company, and the Pacific Gas and Electric Company.

Installation of the systems requires considerable care and planning, as in nearly all cases the power network is in complete operation. It is essential that the new equipment, while being installed, shall not interrupt the service. It is easy to imagine the uproar which would follow the false operation of a substation feeding power and light to the general public. The explanation that the service was being improved might be received with sardonic laughter.

Among engineers of Bell Telephone Laboratories who have worked on the development of supervisory control systems are J. C. Field, J. J. Catogge, L. J. Burns, A. H. Miller, J. B. Harlow (now of Western Electric) and L. E. Coon (now of Graybar Electric).

Still further development and improvement in supervisory control systems may be expected to follow the general advance of the electrical art, and particularly progress in the field of electrical communication.

The Age of Remote Control

To our own era we sometimes give the name "The Age of Electricity." But we are really well along in a new epoch—"the age of remote control" of energy sources.

Our modern life has to do with machines for varied purposes, each controlled by a switch or button, a valve or throttle. When energy is thus released to the machine there is no further demand on the intelligence or skill of the operator, and the machine proceeds to perform the characteristic series of operations for which it was designed. Engineers and research scientists are constantly placing at the disposal of the large mass of scientifically untrained people complicated machines to accomplish their every desire.

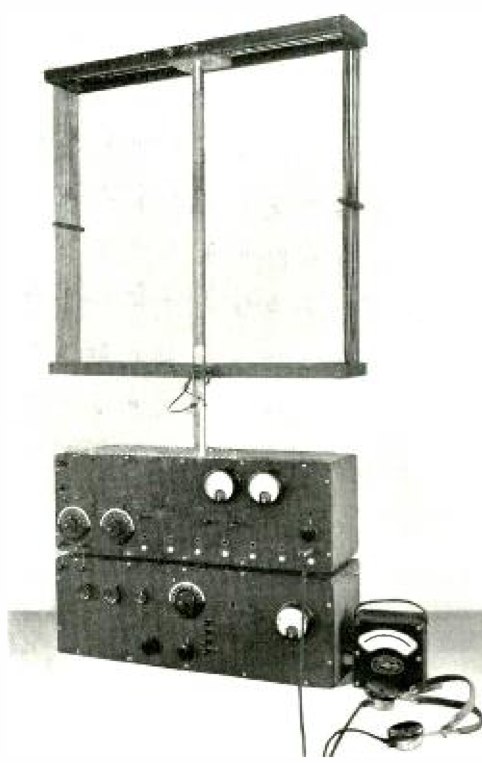
Of human desires one of the most important is for means of communication. The complexity of the modern machine-switching system of telephony, the mechanical and electrical problems which were solved in its development, and its underlying engineering features may remain unappreciated by a subscriber who need only turn his dial switch to control the energy at a whole series of successive points remote from himself. The machine has been designed to do his bidding; but the design and its preliminary scientific and engineering studies have required the coordinated efforts of a large number of highly trained engineers.

New Portable Sets Measure Radio Transmission

By Axel G. Jensen

Whatever may be the value of the annual transatlantic broadcasting tests, there is no doubt that the radio listener has profited substantially, if indirectly, from another kind of transatlantic test. An integral part of the investigations which led up to the successful two-way telephone talks of March 7th last was a long series of measurements of radio field-strengths. For this purpose, apparatus was developed by C. R. Englund,* and later a modification of it was applied to a study of field strengths of broadcasting stations. In particular, the set shown in the figure was used to make a map of field strength in and around New York City,† which gave the first precise information to back up listener's complaints of poor reception in certain parts of the city. "Shadows" cast by hills and steel buildings were plainly shown to be responsible for "dead spots," for instance that near Central Park, Manhattan. During these tests the set was mounted in an open passenger automobile, which made it possible in a comparatively short time to obtain a great number of measurements extended over a large area, since each measurement takes only a few minutes for a skilled operator.

Procedure in making a field strength measurement with a set as shown in the picture is as follows: The upper box contains the receiving unit and is in principle a double-detection set provided with a sensitive meter in the plate circuit of the second low-frequency detector. The lower box contains an oscillator and a potentiometer arrangement for producing for comparison a single voltage of known amplitude. The first part of a measurement consists in tuning in the signal to be measured and adjusting the gain of the receiver so as to obtain a suit-



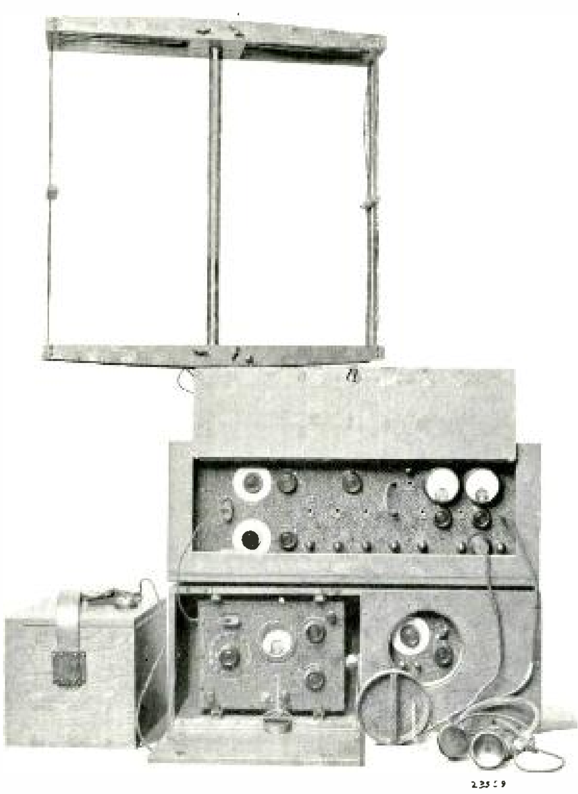
Old-type field-strength measuring set

* *C. R. Englund, Proc. I. R. E., February,* 1923; *Bown, Englund and Friis, Proc. I. R. E., April,* 1923.

† *Bown and Gillette, Proc. I. R. E., August* 1924.

able deflection on the detector meter. Next the oscillator is started, and its local signal adjusted by zero beating to the same frequency as that of the signal. Then the loop is disconnected from the circuit and replaced by the potentiometer arrangement. The locally-developed signal-voltage across this potentiometer is now adjusted to the same value as the incoming signal-voltage across the loop, as indicated by the reading of the detector meter. It is possible, knowing this voltage, the frequency of the signal and the geometrical proportions and electrical constants of the loop, to calculate the strength of the incoming signal.

The strength of radio signals is generally measured in microvolts per meter. An idea of magnitudes commonly encountered may be had from the following examples: The strength of signals from station WEAF, as measured in Cliffwood, N. J., is about 8,000 to 10,000 microvolts per meter, while measured across the Hudson River opposite our West Street building it is of the order of 50,000 to 100,000 microvolts per meter. Station WGY, Schenectady, when transmitting on super power, gives in the daytime a field strength at Cliffwood, N. J., of about 50 microvolts per meter. All measurements on broadcast stations are measurements of the "carrier" radiation, and may be made whether the radiation is being modulated or not.



Type of set now in use

The rapid growth and the increasing importance of radio broadcasting have made portable measuring sets increasingly useful. The original sets, the operation of which was described above, have had two years of almost continuous use in the field. They were originally designed for laboratory use, and are now practically worn out under this field service. Several new portable measuring sets to take their place have recently been completed and delivered to the American Telephone and Telegraph Company.

The new sets embody several improvements suggested during the use of the older type. They are of a more rugged construction, although about the same size and of faster operation. They are also more nearly weather-proof in construction, mechanically as well as electrically.

With the older sets, as was said earlier, it was necessary in order to compute the field-strength to know the electrical constants of the loop: that is, its inductance and resistance for each frequency with which it was used. In field use, moreover, it was found that the resistance of the loop change considerably with the weather, on account of varying humidity, so that in order to avoid errors it was necessary to measure this resistance several times a day. Measurement of resistances at high frequencies is quite complicated, especially under field conditions, and to do this several times a day is very inconvenient, and causes quite a loss of time. The inductance of the loop, on the other hand, remains constant and presents no such difficulties as does the resistance.

The main improvement, therefore, in the new sets has been the adoption, for broadcasting frequencies, of a method used before only for lower frequencies, which does not involve the measurement of loop resistance. By this method the loop is kept in the circuit continuously, and receives both the distant and the locally generated signals. The local signal is introduced directly into the loop circuit across a small resistance placed in the middle of the loop. Because the incoming signal and the local signal are both introduced in the same manner, a knowledge of the electrical constants of the loop becomes unnecessary. This method, however, requires very efficient shielding, since the loop is in the circuit all the time, and it is very important that the local oscillator shall introduce no stray energy into the loop. The oscillator is, therefore, enclosed in a double metal box, as may be seen in the right half of the lower box, as pictured above. During measurement the outer box, which is copper-lined, is closed by a tightly fitting metal cover, thereby surrounding the inner box with its oscillator by a continuous shield.

The author making a test in the field

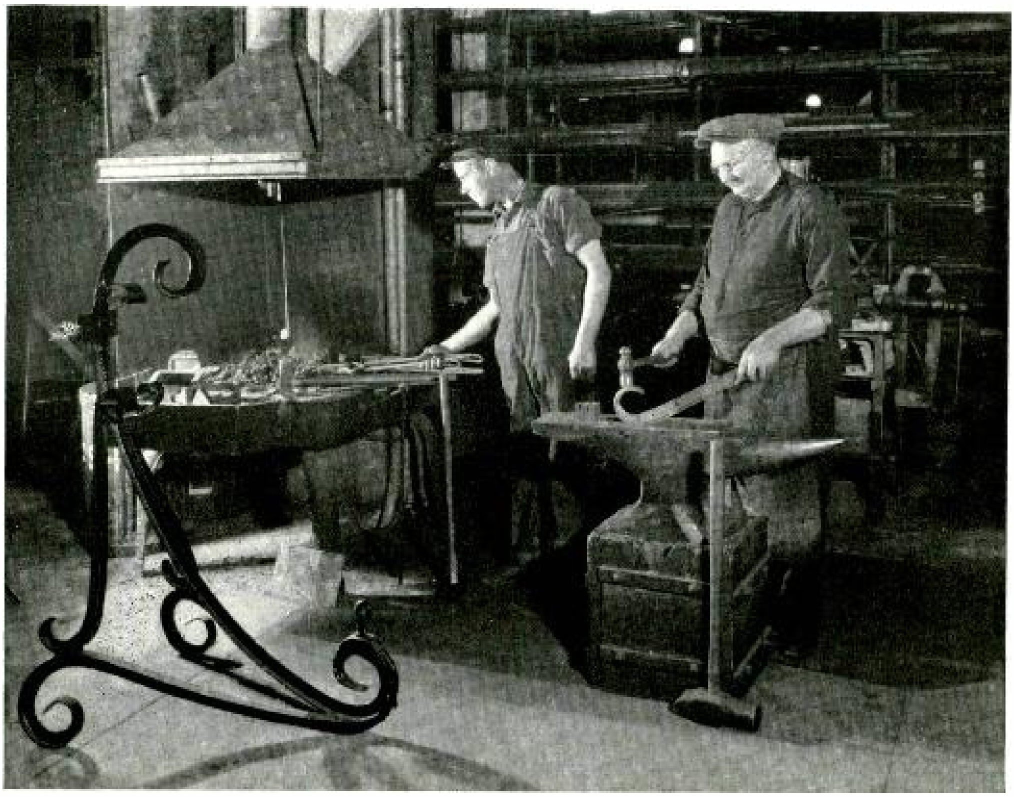
Herbert E. Ives attended the optical Convention in London April 12th to 17th. This is a general meeting of the physical, astronomical and similar societies which are concerned with modern problems of optics.

Professor Hugh Scott Taylor, Professor of Physical Chemistry and acting head of the Department of Chemistry in Princeton University, addressed members of our Chemical Group and others who were interested on the topic, "The Mechanism of Activation at Catalytic Surfaces."

Harvey Fletcher sailed for Europe on May 14th aboard the *Tuscania*. While in London he will attend the international conference on the question of a transmission reference circuit.

At the Washington meeting of the American Physical Society papers were presented by L. W. McKeehan and P. P. Cioffi and by J. A. Beck.

Sergius P. Grace accompanied the International Electro-technical Commission on its tour of the eastern section of the country.



Patrick Conway, smith, and his helper, Jack Lyons, forging the brackets for our new street lights. The brackets were designed by J. G. Motley, Assistant Plant Manager

Club Activities

The Club bowling league finished a most successful season on Friday evening, April 23rd, with the Coils winners in "A" class, Lamps in "B" class, and Signals in "C" class.

The winner of "A" class was not decided until the last game had been rolled. Plugs and Coils were tied on the last night; the Coils won the championship by taking three straight. E. P. Bancroft finished the season with an average of 189.16 for eighty-four games, H. C. Dieffenbach was second with 186.18, and C. Dusheck third with 185.98.

In addition to the prizes donated by the league, each man on the three winning teams will receive from the Bell Laboratories Club an order on Alex. Taylor & Co. for sporting goods.

On Friday evening, April 30th, the Club had a special night for all the bowlers. No fees were collected, and special prizes totaling one hundred and eight dollars were offered to the bowlers making the best scores over their season's averages. Joe Dusheck, of "A" class, made the best showing by rolling a total of 659 for three games.

We are printing several scenes photographed by the hikers. From the pictures printed last month and these we have here, you will see that the country through which they travel is always interesting. This month the Hiking Club again offers both variety in walking and in the length of the hike, in order that you may join them and enjoy the country with them when it best suits you.

Saturday, June 5th, the hike will be through the woods and cross country about six miles from Heathcote to White Plains, with a campfire supper somewhere along the trail.

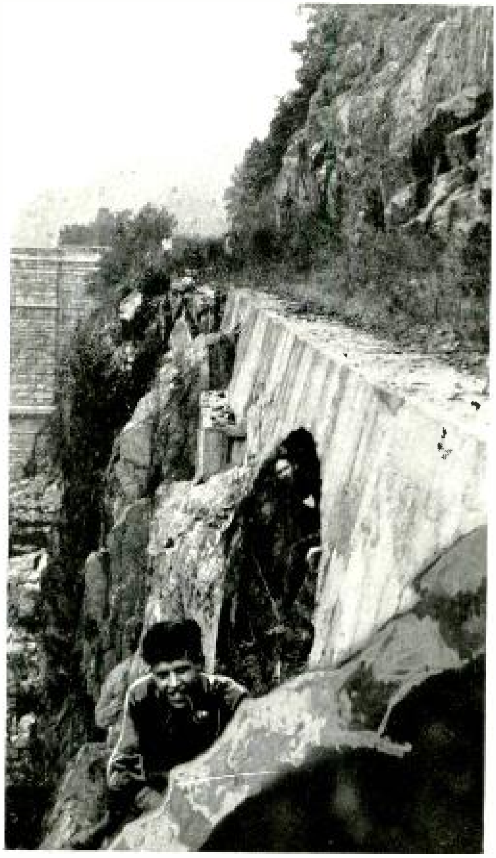
Sunday, June 13th, along the Mianus River, Connecticut. This day they start at Greenwich and walk along shore to Bedford, then ride by bus to Mount Kisco.

Nelson E. Sowers

Saturday, June 19th, they are off to Jersey, walking from Milburn to Montclair over the bridle path on top of the mountain.

Sunday, June 27th, they will take

you to Long Island, walking from Sands Point to Port Washington along the shore. This walk is about twelve miles, but the walking is easy and delightful.



Above the Croton dam

Each week the full information regarding railroad trains, the time of starting and the meeting place are listed on the bulletin board; but if you want any special or advance information Miss P. Barton or Mr. N. E. Sowers will be very glad to tell you all about future hikes.

CONGRATULATIONS ARE DUE TO the bridge players for their splendid games. The women's and men's tournaments were both successes. In the women's tournament Miss Thuebell started out to win the first evening, and although she did not lead every night she finished in first place, with Miss Munn and Miss Lynch in the second and third places.

After the women's tournament was over a game was played between the men and the women which was enjoyed so much that a similar game was played two weeks later. A first prize was awarded to both the man and the woman holding the best score. The struggle for first place was pretty close, as the score shows:

D. G. Grimley	2494
Miss M. Lynch	2468
H. M. Hagland	2153
D. H. Wetherell	2096
G. T. Lorance	2085
Miss M. Kreer	1948
A. Zitzman	1924
Miss M. Thuebell	1869
J. G. Dusheck	1815
C. E. Boman	1812

Keen competition was shown throughout the entire season in the men's bridge tournament, and it was not until the last night that the winner of the season prize was decided. At the start of the play of this final session H. M. Hagland was leading, but the gods of luck combined with good playing brought to D. H. Wetherell the first prize, which was donated by the Club.

This group had an average of twenty-eight players, and met once a week.

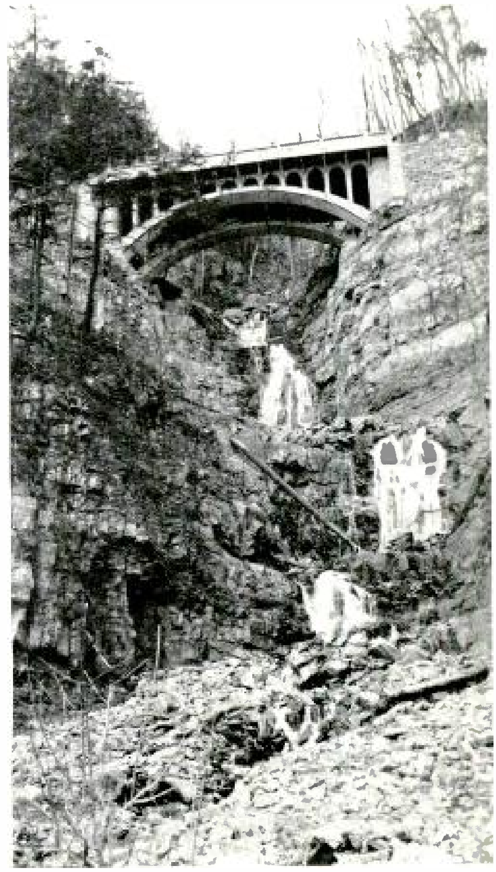
Following is the order in which the first ten players finished:

1-D. H. Wetherell	6-V. Borlund
2-H. M. Hagland	7-J. C. Field
3-G. T. Lewis	8-A. Zitzman
4-L. P. Collins	9-C. A. Schlenker
5-H. B. Barber	10-M. N. Smalley

TICKETS which entitle Club members to all privileges at the Brighton Baths on Saturdays, Sundays and holidays are now available. These tickets are one dollar each for Sundays and holidays and fifty cents for Saturdays. Tickets should be presented at the season ticket entrance to obtain a house check, thus eliminating all waiting in line. Club membership cards must be shown at time of presenting admission tickets.

During the past season fifteen hundred Club members enjoyed the bathing at Brighton Beach, and it is hoped that an even greater number of members will take advantage of this exceptional privilege during 1926. Your department representative can supply you with any number of tickets you may wish to purchase.

Although the swimming classes at the Carroll Club are for the women, don't forget that there are tickets available for all to swim at the Hotel Shelton pool, Forty-ninth Street and Lexington Avenue. The Club secretary has tickets that make it possible for you to enter the pool for one dollar.



Along the Palisades

ON THE EVENING of May 27th the Bell Laboratories Club Symphony Orchestra and the ever-willing Colvoy Quartette journeyed to Kingsbridge Road and Sedgewick Ave., the Bronx, to entertain the 800 or more patients at the United States Veterans' Bureau Base Hospital No. 81.

The Western Electric Post, No. 497, of the American Legion sponsored this hospital visit as a part of its welfare program. All expense incurred in taking our artists to dinner and transporting them to and from

Our hikers take to the trees

the hospital was defrayed by the Legion Post.

BASEBALL HISTORY repeated itself on Thursday evening, May 13th, when our team defeated the New York Telephone, Manhattan, team in the opening game of the Bell System Baseball League.

The Laboratories Club delivered a brand of baseball that was a pleasure to see. Pitcher Kuhlman had the Telephone men at his mercy throughout the entire game, allowing only three hits and one run, which was the result of a freak home run which hit the cinder running track in deep center and bounced over the fence. The Laboratories men smashed out eight hits, which they made count for five runs; the best of the hits was a long double by Trottere with two men at bases. The game was one of straight, clean baseball from the first inning.

The games during June are:

Bell Laboratories Club vs. New York Tel., Long Island, June 14th.

Bell Laboratories Club vs. Western Electric Co., G. H. Q. June 21st.

Busses leave at 5:05 P. M. and game starts at 6 P. M. sharp. Bus leaves for New York at 7:45 P. M. Those who wish to see the games may arrange for seats in bus by calling D. D. Haggerty. The fare is fifty cents for the round trip.

THE INTERDEPARTMENTAL BASEBALL LEAGUE opened its season on Saturday, May 15th. The first game of the double header was between Equipment and Commercial, and resulted in a 4-4 tie. The second game was won by the team representing Apparatus Development when they defeated the Tube Shop by a score of 6-3.

All games, both in the Bell System League and the Interdepartmental League, are played at Erasmus Field, Gravesend Avenue, Brooklyn.

THE WOMEN'S SWIMMING CLASS at the Carroll Club is to be continued through June. There will be one class on Friday nights from 5:30 to 6:00 with Miss Steele in charge. Miss E. D. Bolan has been in touch with all the women who have been in either of the two classes, and has found that a good number of them are still interested, making it possible to continue the lessons. It may be of interest to know that ten per cent. of our women have been attending these classes at the Carroll Club since they were opened in April.