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Some Facts about Frequency Measurement

By W. A. MARRISON
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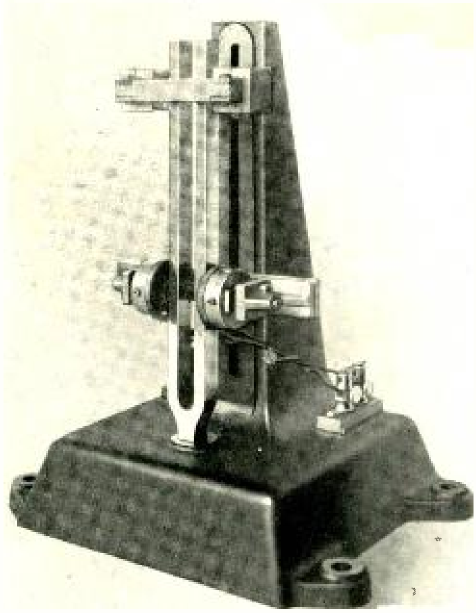
IN electrical communication we are concerned with frequencies ranging from less than one cycle to 100,000,000 cycles or more per second. In a considerable portion of this range it has become necessary in some cases to measure frequencies with an accuracy approaching one part in a million. It will not be long before it will be necessary to generate currents with frequencies having given values within the same limits, the distinction between the two cases being that in the latter a very precise method of adjustment must be employed in addition to a precise method of measurement. Systems have been developed such as television involving synchronizing at a distance without the use of a control channel, in which it is desirable to maintain frequencies constant to one part in 10,000,000, and it seems now that over reasonable periods this accuracy will be attained with little difficulty. This does not imply that the frequencies would be adjusted to a specified absolute value with this accuracy, but only that two or more independently controlled frequencies would retain their original values within this limit.

It has not been many years since, when one wished to calibrate an oscillator in the audible range, he listened to the tone from a struck tuning fork and compared with it a corresponding tone from the oscillator in question. This method is subject to obvious personal errors largely due to limitations of the ear, in addition to probable errors in calibration and errors due to temperature coefficient, varying amplitude, variable mounting, and abuse of the fork. High frequencies were commonly measured by means of a wave meter, the calibration of which was computed from the circuit constants. This method also is subject to considerable errors, chiefly in determining the values of the circuit constants to use in the formula expressing the frequency. It is not surprising, therefore, that frequency measurements made at different places by different methods and observers failed to agree, in some cases by very considerable amounts.

Since frequency is defined in terms of time, the logical method for mak-



The hundred-cycle tuning fork, showing the driving coils (above) and the pick-up coils (below) from which the vacuum-tube circuits are controlled

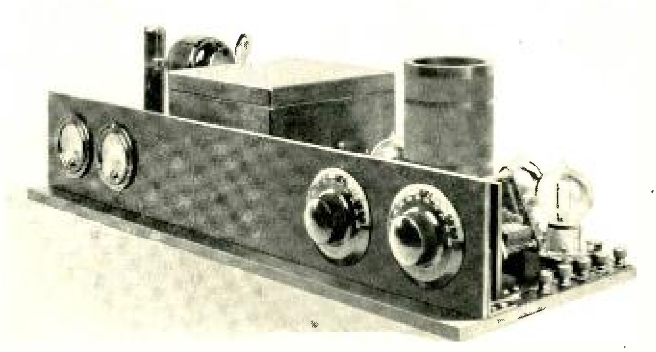
ing accurate determinations is to count the number of cycles during an interval long enough to be measured with high precision, while keeping the rate so constant that the mean frequency over the period may be taken as the value at any instant. By employing as the standard of frequency the reciprocal of the accepted standard of time — the period of the earth's rotation on its axis — the measurement is made independent of any artificial "measuring stick" that might be set up. As a matter of fact, it is not possible to give a standard of frequency any physical embodiment, as is done in the case of length and weight standards, because frequency, like velocity or power, is a rate, not a material quantity.

It is comparatively easy to measure one frequency in terms of another, so, rather than make each measurement of frequency in terms of time directly, it is preferable to make all such measurements in terms of a reference standard. Such a standard should be constant and be capable of slight adjustment so that it may be maintained at its nominal value within such narrow limits that the departure is always considerably less than the error in making subsequent comparisons. Obviously any number of such reference standards may be

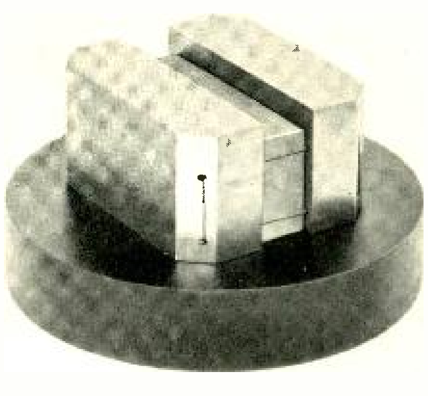
This clock is driven by the hundred-cycle motor which is seen through the window

set up without affecting the relative accuracy of subsequent measurements made in terms of them, since the ultimate standard is, in all cases, the rate of the earth's rotation. The frequency of a reference standard should be chosen so as to be most convenient for use in a specified range.

The reference standard, in terms of which most of the precise measurements of frequency in the Bell System have been made since 1923, consists of a 100-cycle regeneratively driven tuning fork. In order to determine the frequency accurately, a synchronous motor is operated by current whose frequency is controlled by the fork. This motor drives a cycle-counting mechanism which, for convenience, is made in the form of a clock. The number of poles on the motor and the ratios in the gear train are chosen so that when the frequency of the fork is 100 cycles exactly the clock keeps accurate time. Any departure in the rate of the clock is, therefore, a measure of the error in the standard. For the purpose of making frequency comparisons with this standard, current at 100 cycles obtained from the vacuum tube circuit is distributed wherever required.



This oscillator is controlled at 50,000 *cycles by the quartz crystal*



A 50,000-*cycle quartz crystal in its mounting*

The fork, being made of ordinary tool steel, has a temperature coefficient of one part in 10,000 per degree centigrade and must therefore be controlled to within about 0.01°C. in order to reduce sufficiently the variations in frequency due to temperature. In normal operation the frequency controlled by the fork may be depended upon to within one part in 100,000.

In recent years it has become necessary to measure higher frequencies, and to measure all frequencies with greater precision, than formerly. To meet the new conditions, a new form of reference standard has been developed in the form of an oscillator controlled by a quartz crystal, with auxiliary equipment to facilitate determining and regulating its frequency and for supplying current at frequencies convenient for comparison over an extended range.

The equipment for determining the frequency of the crystal is somewhat similar to that used with the fork standard. It consists of a clock driven by a synchronous motor operated by current controlled at a comparatively low frequency which is an exact submultiple of the frequency of the crystal. The frequency and gear ratios are so chosen that when the high frequency has its normal value the clock keeps accurate time. Any variation in the rate of the clock is, as with the fork-clock, a measure of the error in the standard. So constant is the frequency of the crystal that the clock controlled by it keeps time accurate to one tenth of a second a day.

The frequency of the crystal-controlled oscillator in use at present is 50,000 cycles and the frequency derived from it to operate the motor-driven clock is 1000 cycles. Provision is made for distributing throughout the Laboratories currents at both of these frequencies for use in making frequency comparisons.

The temperature coefficient of the crystal used is considerably smaller than that of an ordinary steel fork, but in order to attain the required accuracy it is necessary to control the temperature to within one or two hundredths of a degree. Atmospheric pressure variations change the frequency in the order of one part in a million, but this can be avoided at any time by mounting the crystal in a sealed container.

To obtain a better idea of the constancy of crystal control, two oscillators having nearly the same frequency were set up so that variations in the low difference-frequency could be determined with high precision. The accuracy of the beat-frequency measurement, when interpreted as the accuracy of the oscillator, is increased many times. By the method used, the relative accuracy, that is, the accuracy of one oscillator regarding the other as constant, could be determined to one part in 500,000,000 during each 5-second interval. Using this method the relative rates were measured over a period of several hours. There were slow variations, amounting to a few parts in a hundred million, having the period of thermostat operation, but over an interval of about four hours the total variation was less than one part in 10,000,000.

As long as the length of a day remains constant within measurable limits, the present method of deriving a working standard of frequency will undoubtedly serve adequately the needs of the Bell System. But the astronomers tell us that at the present rate the length of a day will change about one second during ten years. This is an amount that would soon cause a serious discrepancy between the reference standards and the fundamental standard if the variation continues in the same direction. If the rate of the earth's rotation continues to change, it will be necessary, either to make corrections from time to time in the reference standards, or to adopt a new technique in which something more fundamental than the rate of the earth shall determine the standard of frequency and ultimately, perhaps, the standard of time interval as used in the CGS system.

Continuous Charging for Automatic Branch Exchanges

By LEWIS EARL
Systems Development Department

A VITAL problem in the engineering of private branch exchanges is to provide a power plant of comparative simplicity and low cost where the attendance and supervision required is a minimum and where the floor space taken up by the plant is small. The last requirement assumes considerable importance when it is considered that these private exchanges are frequently installed in office buildings where the annual rent per square foot of floor space is high.

To meet the problem of minimum attendance, two methods of charging are possible. One, used with the larger private branch exchanges, charges the battery automatically when it reaches a predetermined state of discharge. Such a system has already been described in BELL LABORATORIES RECORD.* With an alternative method the charging equipment is connected to the battery continuously and so adjusted that at average load a small trickle charge only flows into the battery. At heavier loads the battery is discharging and at lighter loads it is being charged. As a result the battery never gets extensively discharged and at least once a week become substantially fully charged. This method is particularly suitable for the small private branch exchange, and equipment and circuits have been designed to make two sizes of power plant available: one which will handle up to two and one-half amperes and the other up to five amperes under maximum load conditions in the busy hour.

These small power plants are designed to operate on the local lighting circuits of either direct or alternating current. When the source is direct current a small motor-generator set is used for charging; and when it is alternating current Tungar rectifiers, which have proven so satisfactory for the ordinary radio batteries, are used. The radio type LXL storage battery is employed which also is standard for the larger private branch exchanges where automatic charging is used. Due to their production in large quantities and their wide distribution these batteries are relatively inexpensive and readily obtainable.

These continuous-charging power plants were designed principally for use with the 740-A dial system P.B.X.* which requires a voltage maintained between forty-four and fifty volts. A battery of twenty-three cells was selected as being most suitable for this voltage range. As this battery might reach a voltage approximating fifty-eight volts when fully

* *November, 1926, pp. 87-90.*

* *Described on pages 399-402.*

charged at a substantial rate, some form of regulation was necessary in order to meet the fifty-volt upper limit. Two groups of counter-EMF cells, each containing two cells, were used to provide the required voltage

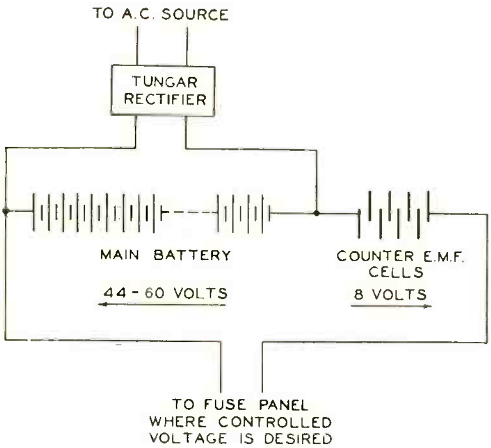
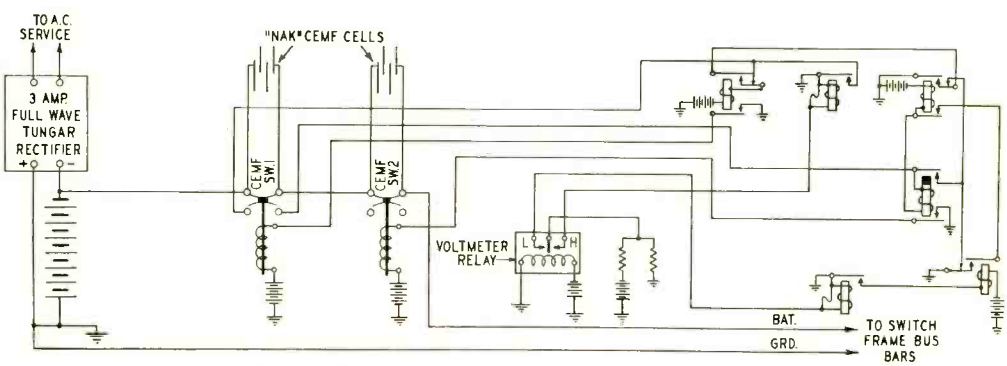


Diagram showing method of connecting counter-E.M.F. cells into circuit to control voltage

control. These counter-E.M.F. cells are connected in the discharge lead from the battery and develop an electromotive force opposing that of the battery itself. The accompanying diagram shows how they are connected into the circuit to cut down the high battery voltage when necessary. Whenever they are not required, they are cut out of the circuit.

Counter-EMF cells are used to a considerable extent in telephone and telegraph power plants for voltage regulation, but the ones previously standard throughout the Bell System are of the lead-acid type. For this P.B.X. power plant, however, a newly-developed cell, known as the NAK, has been used. It has pure nickel electrodes in an alkaline solution. The superiority of the nickel-akaline cells is evidenced by their negligible electrochemical capacity as compared to the lead acid type, and also by their considerably longer life and reduced maintenance. Neither the lead nor nickel counter cells have active material and so neither should store a charge. Actually, however, the lead type is somewhat active electrochemically so that a small charge is stored. The negligible activity of the NAK type makes it possible to short-circuit them in order to cut them out of the circuit, which often simplifies the switching.

The introduction or removal of the counter-EMF cells from the discharge circuit is controlled by a voltmeter relay. When the fuse-panel voltage reaches fifty the voltmeter relay closes its "H" contact; and through a chain of relays the first

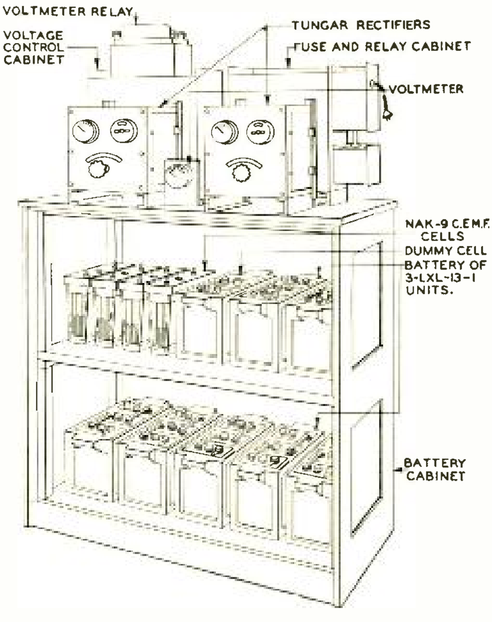


Circuit diagram showing method of cutting counter-E.M.F. cells in and out of circuit counter-EMF cell switch is operated. This removes the short circuit from the first group of two counter-EMF cells whereupon the fuse-panel voltage drops below fifty and the voltmeter relay breaks the "H" contact. If, due to charging conditions, the voltage again reaches fifty, the voltmeter relay again closes its "H" contact and switch No. 2 is operated. This removes the short-circuit from the second group of cells, causing the voltage again to drop below fifty, after which the voltmeter again breaks its "H" contact.

When, due to increased load, the fuse-panel voltage drops to forty-four, the voltmeter relay closes its "L" contact and through the chain of relays switch No. 2 is operated and places a short circuit across the second group of cells. The voltage now rises above forty-four with the consequent opening of the voltmeter relay "L" contact. If the voltage should again drop to forty-four the voltmeter relay would of course again make on its "L" contact and, through the relay chain, switch No. 1 would be operated and a short circuit be placed across the first group of cells. Following this the voltage would again rise above forty-four and break the voltmeter relay "L" contact.

The chain of relays is so arranged that any part of the above cycle of operation is possible. Switch No. 1, for example, may be operated and then released without operating switch No. 2. If load requirements are such as to require both switches to be operated or released switch No. 2 is always the second one to operate and the first to release. Where the voltage range to be maintained on the switchboard equipment is liberal, such as 20-28 volts, the voltage control equipment described is not required.

An accompanying illustration shows the power plant as it is arranged where alternating current service is furnished. It will be noted that the complete power plant is installed near the switch frame. Its comparative simplicity can be visualized, as it consists of only the charging sets with metal cabinets housing the voltage-



General arrangement of power plant where alternating current is available

control, fuse and relay equipment, separately mounted voltmeter and voltmeter relay, and a cabinet enclosing the twenty-three cell storage battery, the top of the cabinet acting as the foundation for all of the other power equipment. The voltmeter relay, on account of its sensitiveness to stray fields, is separately mounted on a wooden block on top of the voltage-control cabinet.

Acoustic Filters

By W. P. MASON
Research Department

ALL air waves can be considered as made up of vibrations of different frequencies. At the low end of the scale are such steady or slowly varying air currents as the wind, whose frequencies are practically zero, and at the upper end are buzzings of certain insects and other vibrations so rapid that the ear

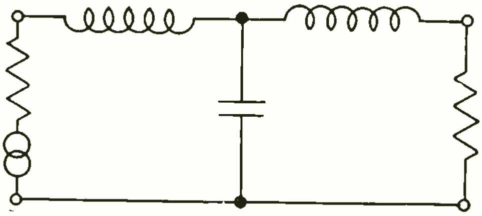
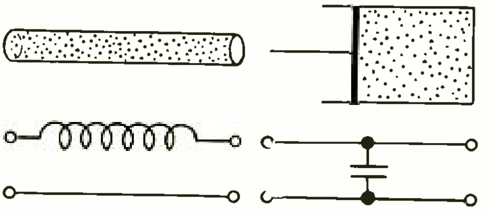


Figure 1

is insensitive to them. It is comparatively insensitive as well at frequencies up to 100 cycles per second, while sounds below about 16 cycles per second cannot be heard at all.

It would often be desirable to separate air waves of various frequencies. For ventilation free movement of the air is necessary, yet some waves of higher frequencies, when they constitute "noise," are most objectionable. Similarly it would often be desirable to reduce the noise components in the exhaust puffs of locomotives. Other instances come readily to mind. Such a separation of waves can be accomplished by an acoustic wave filter.

A wave filter is a device for differentiating between frequencies of wave-motion just as a screen or porous filter separates material of different sizes. Electric wave filters have long been employed in the telephone plant. Figure 1 shows a diagram of one of the simplest types, a low-pass filter with terminating resistances, which passes currents up to a certain critical frequency known as the cut-off frequency and suppresses those above that point. When only the series inductance is interposed between the two terminating resistances, it introduces little change at low frequencies, but as the frequency increases the inductance considerably decreases the current. Similarly the condenser alone has slight effect at low frequencies, but at high frequencies it shunts most of the energy through itself, allowing only a small part to reach the terminating resistance. It might be expected that the combination would allow low fre-



Figures 2 *and* 3—*Acoustic and electrical analogues*

quencies to pass and attenuate the higher frequencies to an increasing degree. Such, however, is not the case; the filter allows a band of frequencies to pass almost without attenuation, and highly attenuates any currents above that band. Other types of electrical filters pass only the high frequencies, or pass only those in a band between definite limits, highly attenuating all others.

Similarly, filters can be made from acoustic elements, although the mathematical treatment is not as simple as for electric filters.* The air in a short tube, if the rate of vibration is low, can be considered to be moving as a whole, and hence to interpose a mass reaction against any force which tends to move it. A sort of analogy exists between this effect and the electrical inductance of a coil, and also between a closed chamber into which a piston is working and a condenser to which a direct voltage is applied. Combining these simple elements as shown in Figure 4 we have a structure some-

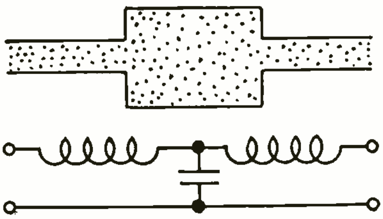


Figure 4—Acoustic and electrical low-pass filters

what analogous to a low-pass electrical filter.

These analogues, however, are not close. While it is possible to make electrical elements which are nearly pure inductances, capacities, or resistances, these qualities cannot be so well segregated in acoustic devices, at ordinary voice frequencies. Thus the air in the small pipe does not move as a whole, but is traversed by a wave which takes a finite time to go from one end of the tube to the other. Similarly, the enclosed chamber does not at once oppose the action of a force, as does an ideal condenser, but only after a finite time. For slowly-varying pressures or waves of low frequency, this short time of transmission makes very little difference in the action, but when the time of transmission approaches the time of oscillation of the wave, a marked difference occurs.

A simple acoustic filter is shown in Figure 5, consisting of a main con-

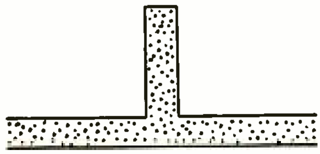


Figure 5—An acoustic "line" with a side-branch

ducting tube with a side branch closed on the end. The electrical equivalent of this structure (Figure 6) consists of a line with distributed capacity and inductance shunted at its center by a similar line open-circuited at its end. Some propogation properties of these systems can be deduced by inspection.

Whenever the shunt line is in an anti-resonant condition, that is, when the reflected wave returns in exactly opposing phase with the incident wave, the impedance looking into the shunt is infinite (neglecting dissipation) since the two waves cancel, and a given pressure produces no velocity in the side branch. Under this condition, the side branch will exert no influence on the transmission. The attenuation of the filter will be only that of the main branch, and if there is no dissipation this attenuation will be zero. These anti-resonant points occur when the frequency is such as to make the length of the shunt line 0, 1, 2, etc., half wave lengths and they mark the centers of the pass bands of the filter. Hence, this type of filter passes a low-frequency band,

** The possibility of designing acoustic filters whose elements play roles approximately analogous to those of the elements of electric filters was first pointed out by Prof. G. W. Stewart of the University of Iowa.*

a second band whose central frequency is f, a third band whose central frequency is 2f, and so on.

Whenever the reflected waves are in phase with the incident waves the shunt line is in a resonant condition. Its steady-state impedance is then very small, since the series of reflected waves builds up a very large amplitude, and the ratio of volume-velocity to pressure is large. Under these conditions an attenuation band exists, because the shunt line diverts practically all of the motion from the terminating end. Such a condition of resonance exists at frequencies where the length of the branch is one quarter wave length plus any number of half wave lengths; these frequencies, which bear to each other the ratio 1:3:5:7, and so forth, are therefore the centers of attenuation bands.

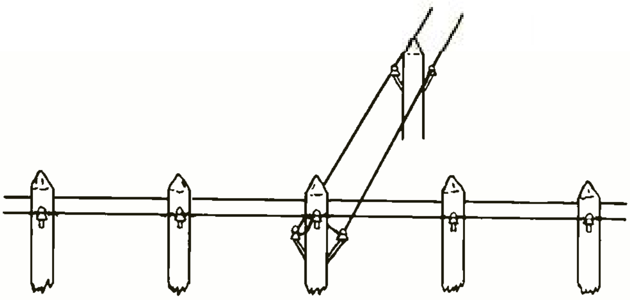


Figure 6—A telephone line with a branch from it analogous to the acoustic system of Figure 5

What part the length of the main tube plays is not so obvious, but analysis* shows that this length determines the relative width of successive pass bands. The most interesting case is where the total length of the main tube equals the length of the side branch, for then all of the transmission bands have the same width. The ratio of the cross-sectional area of the side branch tube to that of the main conducting tube determines the width of the attenuation band relative to that of the pass band. The larger the ratio the greater the width of the attenuation band, for the larger will be the shunting effect.

A more complicated filter is shown in Figure 7. Its main conducting tube, the inside pipe, is generally so small that only the longitudinal vibrations need be taken into account, and with the usual dimensions of the large chamber, radial vibrations need not be considered at the lower frequencies. A longitudinal vibration coming from the pipe travels to the far end of the chamber and is reflected; when it comes back to the chamber wall at the incoming end it is reflected again. When the reflected waves are in phase with the incoming waves, a building up of vibrations occurs until the amount of power passing from the filter into the outlet pipe is equal to that coming in less the amount dissipated in the filter. Since a resonant condition exists at all points for which its length is one-half wave-length, one wave length, or any integral multiple of a half wave length, these frequencies are the centers of successive pass

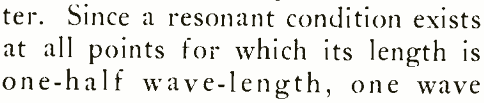


Figure 7—A band-pass acoustic filter

*These relations are discussed more exactly in earlier papers by the present author (Bell System Technical Journal, April 1927, and Physical Review, February, 1928).

bands. On the other hand, when the length of the chamber is 1, 3, 5, etc., quarter wave lengths, the reflected waves oppose the incident waves in phase. Hence the frequencies in this latter series are the centers of attenuation bands. Attenuation bands also exist around the frequencies at which the radius of the chamber is approximately 1, 3, 5 quarter wave lengths, and so forth. There are then two primary sets of attenuation bands with pass bands between; limiting frequencies of all these can be computed from the dimensions of the filter. Maximum attenuation depends on the relative cross-sectional areas of the main tube and the chamber.

Sound vibrations in air were studied long before electric waves on wire were known. A filter like that of Fig. 8 was used by Herschel in 1833. Although acoustic filters are old as compared with their electrical cousins,

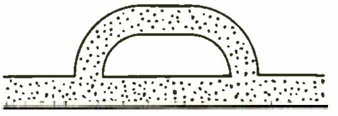


Figure 8

they have not received anything like as much study or development. Acoustic systems are likely to repay further study if for nothing else than for their usefulness in suppressing some of the room noises which are so all-pervasive and which are so annoying to telephone listeners.

A Strange Anomaly

"It is a strange anomaly that men should be careful to insure their houses, their ships, their merchandise, and yet neglect to insure their lives, surely the most important of all to their families, and more subject to loss."—Benjamin Franklin.

If we own a house we insure it for perhaps three-fourths of its value. How many of us have ever stopped to calculate the value of our lives to our families? In terms of affection it is probably beyond price. In terms of earning power, however, it can be easily stated. It is the sum of money which put out at interest would yield a family the necessary yearly income to live according to its present standard. In other words, a man's capitalized earning power, along with his house are among his family's important capital assets. One is of course adequately insured—how about the other?

The payroll deduction plan of life insurance will protect family income and Mr. Lloyd H. Bunting, our insurance expert at the Laboratories, is available to assist in formulating programs and securing insurance.

Apparatus Analysis

By H. L. COYNE
Apparatus Development Department

WHEN apparatus must not only satisfactorily perform its work but give service over a number of years at a minimum cost, its design must involve not only the arrangement of parts to perform a desired end but a detailed study of each element of the apparatus. This study is intended to insure each part's proper working with the whole and to make certain that it will withstand the wear and tear of continual operation with a minimum of maintenance expense and with the lowest consistent first cost. For these studies, the designer invokes the cooperation of appropriate members of the Apparatus Analysis group.

Apparatus analysis requires of those who practice it extensive and detailed knowledge of both mechanical and electrical elements. In the former classification must be considered machine parts such as screws, bolts, rivets, springs, and bearings, and the effect of temperature, moisture, wear, and vibration on successful operation. It is not true, as it appears to the layman, that these parts are simple things about which there is not much to be known. The strength of a machine screw, to take an elementary example, and the force with which it holds two parts together with a given tightening torque, depends not only on its size and the material of which it is made or with which it is plated but on the size, type, and pitch of its threads. A detailed knowledge of the duty cycle to be required of it must be checked against the various types and sizes of screws available if the best overall results are to be obtained.

Not only must a screw be chosen for its strength and the force it exerts, but the likelihood of its loosening in service must be carefully considered. It is held in place by friction which depends not only on the coefficient of friction but on the total force on the threads and clamped surfaces. This must be given the most careful consideration as it changes during the life of the equipment due to many factors such as the external forces exerted during the operating cycle, the loss of resiliency of the screw and of the clamped materials, temperature changes, and vibration which is a particularly fatal enemy of stable assembly.

In general such knowledge is too detailed and analytical for the use of an engineer who is primarily interested in building the apparatus to accomplish some definite and complicated work. His duty is to coordinate parts so that they will carry out his wishes. He works with the apparatus as an operating unit and analyzes the separate parts only far enough to make sure they will accomplish the tasks he assigns to them. His work is with assemblies, the analyst's with details.

Perhaps no mechanical elements of a piece of apparatus require more consideration than springs. The apparatus analyst must make certain that a spring shall exert sufficient force but yet not too much, or unnecessary wear or shock will result to the apparatus. Then, too, the amount of movement the spring must make, the number of times it must operate, and the temperature changes it must undergo are all factors that vitally affect its design both as to form and material. For best results the studies must extend back to the tempering methods used in its manufacture, for tempering is the vivifying element of spring service. So important is this matter of raw materials that special laboratory raw material specifications are now issued to insure satisfactory and uniform products.

Other mechanical design elements of paramount importance are bearings. Type of bearing and method of lubrication both raise an almost endless series of questions to be answered. The speed for which a bearing is designed is always an important factor. This is particularly true of ball bearings which require, for instance, a certain minimum speed of rotation to keep the balls rolling in the center of the race. If they are specified where the speeds are below this value, excess friction between the balls and the containing cages accelerates the wear of the bearing.

Mechanical features of a design, however, are only part of the entire problem. Electrical resistances, inductances, and capacitances and magnetic circuits and materials all come in for attention. In some cases the Apparatus Analysis group serves only in an intermediate capacity in checking these elements by seeing that each has proper consideration from the appropriate specialized group in the laboratory. Other electrical features such as base-metal contact materials and voltage drops due to contact resistance, are passed on directly by the Analysis group. In one way or another, however, they make sure that every detail of the design has had proper consideration and analysis.

A very important part of apparatus analysis is life testing.* Theoretical analysis although essential for good design must be constantly checked against actual operating results. Apparatus and parts must be subjected to all the varieties of stress and strain that they could ever experience in actual service, and so testing with controlled temperature and moisture conditions is an important function of apparatus analysis.

An allied function is the investigation of trouble in the field. Here the testing is actual operating service and a study of the failures is very fruitful of detailed information which may lead to improvement in design as well as to the solution of the trouble.

In addition the Apparatus Analysis group is instrumental in investigating changes proposed by the Manufacturing Department and as a result recommends many modifications to facilitate manufacture and to lead to cost savings that do not otherwise affect the design. Also they specify limiting conditions or tolerances such as hardness of metals, spring forces, contact pressures, or the required tolerances for resistances, voltages, or other electrical constants.

The necessity for extensive testing to insure at all times the best use of materials and parts again emphasizes

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*Bell Laboratories Record, *January*, 1927, *pp.* 155-159.

the desirability of an Analysis group which specializes in laboratory tests. There is a further gain from having each piece of apparatus carefully studied by distinct groups who naturally scan it from somewhat different viewpoints. The system furnishes an independent check on all designs which can not help but be of value.

For the best results it is desirable to have the two groups work together from the beginning of a design. Consultation during the early stages is bound to speed up the final completion and reduce its cost by eliminating the necessity of retracing steps and the possibility of rejected models or samples. Occasionally the completed drawings are submitted for analysis and at other times models are used for the studies. Tool-made samples naturally come to the Analysis group as an established procedure and form the final basis of analysis.

The results of analysis appear in the form of laboratory reports which describe the apparatus and its purpose. In addition they contain results of tests and may suggest new schemes of arrangement conducive to longer life, simpler construction, lower manufacturing costs, and more reliable operation. In concluding, the reports contain recommendations based on results of an impartial investigation made with all the facilities the Laboratories can command. They are for the immediate use of the designer responsible for the apparatus in question and serve as a valuable future reference library for the use of the various design groups.

Carrier Systems in Australia

J. S. Jammer, formerly of these Laboratories and now with the International Telephone and Telegraph Company, tells in that organization's quarterly for July of the adoption of the carrier-current system in Australia. He states that a marked improvement in service resulted after a three-channel carrier system had been installed between Sydney and Melbourne towards the end of 1925. *The success of this first carrier led to the installation of a six-channel, four-wire system between Sydney and Newcastle. A carrier-telegraph system was then installed between Sydney and Melbourne, and between Melbourne and Adelaide. In all, there were installed* 13,000 *channel miles of carrier-telephone and* 6,000 *channel miles of carrier-telegraph circuits.*

Announcing the 740-A P.B.X.

By J. G. FERGUSON
Systems Development Department

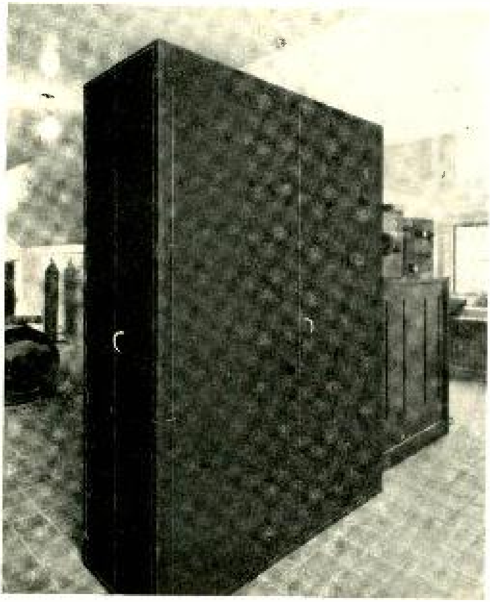
RECOGNITION of the value of telephone service to business houses came so soon after the first telephone conversation that a private branch exchange switchboard was in use at Ansonia, Connecticut, less than five years later. Since then the course of development of P.B.X. switchboards has been steady, paralleling closely that of switchboards for central offices. As telephone messages have taken an increasingly important part in the transaction of business, P.B.X. switchboards to meet a wide variety of traffic situations have been brought out, embodying in each case whatever current developments were appropriate. Introduction of the dial in the Bell System paved the way for the 700-C dial P.B.X., which has all its stations connected to step-by-step apparatus for local and outgoing calls. To complete incoming calls, however, an operator is needed, so the stations are also connected to jacks for manual operation. Though this system is feasible for establishments of almost any size, it is ordinarily only in installations serving one hundred stations or more that it is economical to have the lines appear at combined manual and step-by-step equipment.

The majority of business houses require fewer than 100 station lines and to provide these firms with a more satisfactory dial service the 740-A P.B.X. is now available. The cost of operating the new P.B.X. will be considerably less than that for a corresponding 700-C, due partly to the fact that a cheaper method has been devised for handling its incoming calls. These calls come in not to a manual switchboard with a jack for each line but to a small attendant's cabinet containing lamps and keys. The cabinet, which somewhat resembles a cordless P.B.X., will take up only about one square foot of space on a commercial desk. The attendant can therefore do other work when she is not busy with calls and it is expected that she will be able to give approximately two-thirds of her time to clerical duties.

Attendant's cabinet, located in a butler's pantry. The pictures were taken at the first installation, on a large country estate

Keys and lamps on the front panel

of the attendant's cabinet, when used in conjunction with a standard dial sub-set on her desk, enable her to connect a total of ten central office trunks and P.B.X. tie lines to desired extensions; she can also originate local or outgoing calls. Each trunk and tie line is equipped with two keys and three lamps. One key is used to connect the trunk or tie line to the attendant's telephone or to hold it until a required extension is available, the second key connects a station line to a central office trunk for night service and the three lamps show the status of any call in progress. One of two keys associated with the attendant's line must be operated every



Mechanical and power equipment, in the power house of a large estate. In the foreground, switch frame; to the right, power cabinet

time she dials, and the other every time she originates or transfers a call. Provision of a second cabinet increases the possible number of trunks and tie lines from ten to nineteen, the maximum that can be accommodated in any installation.

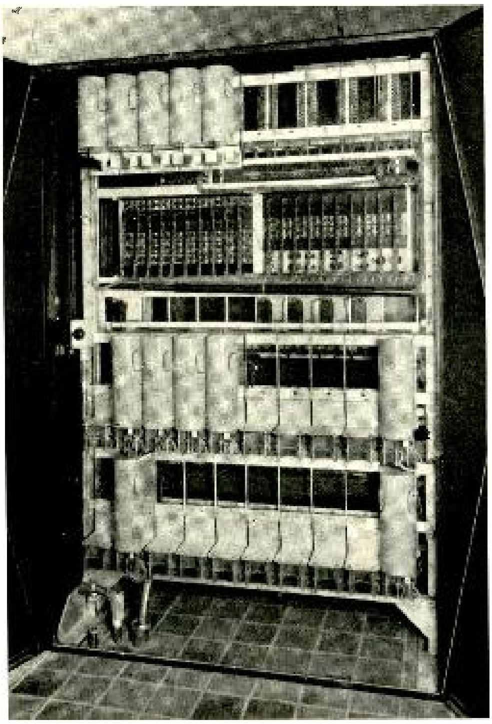
The step-by-step switches and their associated equipment are mounted on the switch frame. One side of this frame provides for the equipment of twenty selector-connectors, nineteen trunk or tie line circuit units and one attendant's telephone circuit unit. The other side is arranged to mount twenty line finders and the miscellaneous equipment associated with the circuits on the frame.

The switch frame is stocked fully wired and equipped except for line and cut-off relays, line finders, selector-connectors and trunk or tie line circuit units which will be provided in accordance with busy hour traffic. When the switch frame is located in an office it will be enclosed in a sheet metal casing finished in olive green.

The power cabinet contains the storage battery with its charging, voltage regulation and alarm equipment.

By operating the dial on the telephone of any station line, it will be possible to connect with any other station line, with the attendant's line, with a central-office trunk (unless the station line is denied central-office service) or with a tie line to an associated distant P.B.X. The dial tie line feature is extremely attractive to a firm which requires efficient communication channels between its branches located in the same city or in adjacent neighborhoods, but too far apart to be served economically by one P.B.X.; the 740-A provides for tie lines to as many as three such distant P.B.X.'s. A tie line permits direct interconnection of two P.B.X.'s without the intervention of the central office operator and the advantage of this arrangement is well appreciated by those of us in the Laboratories who have reason to make frequent calls to 195 Broadway.

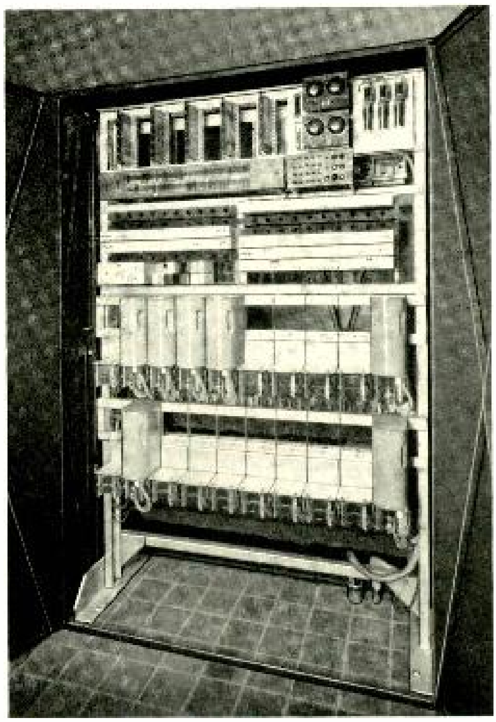
When any call is being originated,



Selector-connector side of the switch frame; at the top, trunk circuit and attendant's circuit equipment

the removal of the receiver from its hook will cause a line finder to operate to connect the calling station to an idle selector-connector. The calling party on hearing dial tone will dial the desired number, consisting of two digits for a station line and one digit for a trunk or tie line, and the selector-connector will operate to connect the calling line to the called station or to select an idle trunk or tie line. Normally the P.B.X. will have a capacity of 88 station lines and 10 trunks to the central office but the station line capacity will be somewhat less than 88 lines where tie lines are provided or where more than 10 central-office trunks are required.

An incoming call will signal the attendant, who will operate a key, find out what extension is wanted, and dial its number. If the line is busy or if the party does not answer, she can dial another extension or hold the call until the desired line is free. When the called party hangs up his receiver, the switches will release without assistance from the attendant, thereby relieving her from interruptions in her other work. On incoming calls



Line-finder side of the switch frame

the attendant can be summoned by a movement of the receiver hook at the extension and she can transfer the call to another line by releasing the switches and dialing the new number. Night service keys allow each trunk to be connected directly to one station line so that night calls from central office can be routed to as many station lines as there are trunks and, since all local and outgoing calls are dialed, a night attendant at the P.B.X. will seldom be required.

From the manufacturing, operating, and cost aspects the equipment of the 740-A P.B.X. is a particularly happy combination. Practically all of its apparatus and circuits resemble corresponding apparatus and circuits in step-by-step central offices so that its manufacturing problems are not new and its maintenance requirements and adjusting procedure are those used in a central office. Its two fundamental units of equipment, the line finder and the selector-connector, are similar in appearance and require similar assembling processes and maintenance routines. Maintenance will be further simplified by the regulating equipment* which will automatically maintain a battery potential between the limits of 44 and 50 volts.

Telephone equipment cannot be manufactured in a day and yet to give efficient service a telephone company should be prepared to supply a P.B.X. to a customer on short notice. Because of the great variations in the telephone requirements of different businesses it is extremely difficult to design a dial P.B.X. which can be speedily distributed and installed. Particular attention was paid to this phase in engineering the 740-A. Like a ready-made suit, it is manufactured in advance to meet the requirements of a percentage of its customers and is easily altered to satisfy the others. Where it fits the traffic requirements without alteration, it is simply necessary to locate the switch frame, the power equipment and the attendant's cabinet and to run their connecting cables; adjustment to traffic needs requires little more than this.

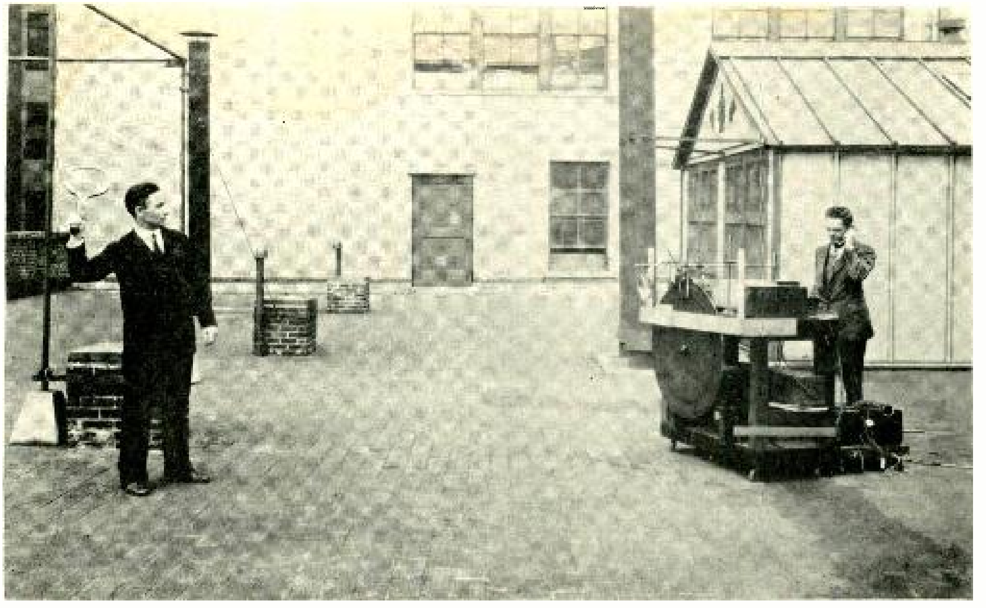
Early orders indicate that the 740-A is a welcome addition to the P.B.X. family.

* *The power plant is described by Lewis Earl on pages* 389-391.

A New Method in Television

JULY 12 saw the first public demonstration of television apparatus using sunlight for illuminating the scene to be transmitted. This marks a definite forward step in the advancement of the art but still leaves a wide gap to be crossed before commercial application of any sort can be contemplated. Two tennis players going through their strokes on the roof of Section G were viewed clearly in the receiving apparatus installed in Room 762. Other actors boxed and danced, swung baseball bats and in other ways provided lively scenes for transmission. The demonstration was given for members of the metropolitan press.

In the first form of apparatus, demonstrated in April of last year, the scene was illuminated by a rapidly oscillating beam from a powerful arc light, and that method limited the scene to be transmitted to a comparatively small area — the area of a person's head and shoulders. The new



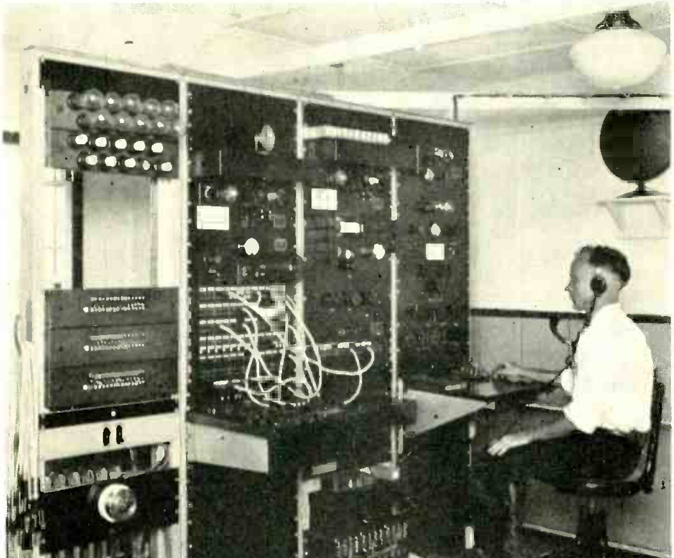
Transmitting unit of the new television system. S. D. Morrison swings the tennis racket and J. R. Hefele is at the controls

development, by using sunlight as the means of illumination, frees television from one of its most serious limitations.

The scene or event to be transmitted is reduced to the form of an image by a large lens, this image being scanned by a swiftly rotating disc similar to that previously employed but much larger. The light allowed to pass by the holes in the disc falls upon a photo-electric cell of extreme sensitiveness which takes the place of the three large cells formerly employed. The experiments show that moving persons or objects can be scanned when at a considerable distance from the lens, so that the focus does not require changing from moment to moment.

The developments which were demonstrated were perfected by Frank Gray working in collaboration with H. E. Ives. Of principal importance is the light-responsive cell, whose greater sensitivity compared to that of the older cells made possible the other changes. The signals sent out are identical in type with those given by the former transmitting apparatus. No important change has been necessary therefore in the receiving apparatus or in the transmitting medium, whether wire or radio, on account of the improvement which has been made in the transmitter.

A general view of the transmitting station and antenna at Deal



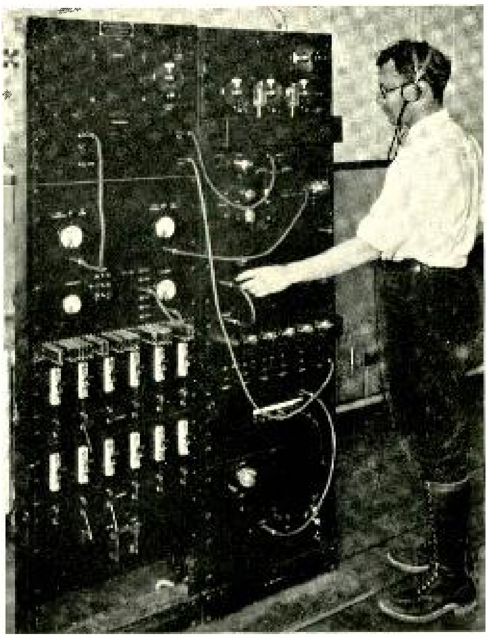
Line terminal equipment at Netcong

The Opening of Transatlantic Service on Short Waves

THE demand for transatlantic telephone service which no longer ago than the first of the year resulted in an average of six to eight calls a day, has recently been producing an average of over thirty with as many as sixty calls on some days. So rapidly has the traffic grown that those of our engineers engaged in designing and erecting the new short-wave equipment to afford an additional channel have found scant opportunity for leisure. Their work is now nearing completion and it is expected that two-way commercial operation will begin shortly.

Short-wave operation so far as our engineers are concerned is not an entirely new thing. It will be recalled that ever since transatlantic service was first opened, we have had a supplementary west-to-east short-wave channel available for use at such times as atmospheric conditions discriminated in favor of short waves as against long waves. Until very recently, however, the British post-office engineers have had no short-wave transmitting facilities for transatlantic telephony and two-way operation upon a short-wave channel is therefore a new undertaking. It is expected that additional short-wave channels will be required in the not distant future to take care of coming growth.

There are several interesting points of difference between the short-wave system and the long. It will be recalled that two-way operation in the case of the long waves has been accomplished on a single wave-length by the use of the single-sideband method of transmission and voice-operated relays which permit of telephone currents traveling in but one direction on the circuit at any instant. Single sideband transmission and working both ways on one wave-length are not now practicable commercially on short waves.



Short-wave radio receiver at Netcong

The voice-operated devices, however, are employed in connection with two slightly different wave-lengths, one of which is used for eastbound speech and the other for westbound speech.

As a matter of fact, the short-wave telephone channel actually has three pairs of wave-lengths available. Our radio transmission studies over the past few years have shown that each of the wave-lengths is particularly suitable for certain times of day and that with the three of them available, operation is normally possible throughout a large portion of the day. One wave-length is normally best during the daylight hours, a second for night conditions and the third for times when part of the transatlantic path is illuminated and part of it is in darkness. Conditions also vary with the seasons.

While operating on any one wave-length, the short-wave transmitter has its frequency accurately controlled by a vibrating quartz crystal placed in a constant temperature enclosure. The change from one wave-length to another is effected by changing the crystal and also the inductances in the output circuits of the various stages of the high frequency amplifier. The equipment is so designed that a change from one wave-length to another can be accomplished in five to ten minutes.

The American transmitting station is at Deal, New Jersey, and occupies the building and grounds originally used for the ship-to-shore experiments in radio-telephony from 1919 to 1922. Reception from England is at Netcong, New Jersey, where buildings have recently been erected and equipment installed. Both stations are connected by wire lines with the Long Lines building at 24 Walker Street, New York. Here the two one-way circuits converge and become a two-way circuit for connection through the Long Distance switchboard to the lines of the Bell System.

Business and the Telephone

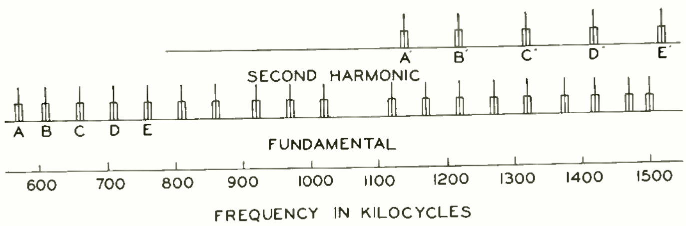
American Telephone and Telegraph reports net earnings of $79,543,000 *in the six months ended June* 30, *compared with* $74,687,000 *in the corresponding period of the preceding year. There is no better barometer of business than the telephone. One might worry if revenues of the telephone companies were on the decline.*

—*Wall Street Journal, July* 18, 1928.

Taking the Harm Out of Harmonics

By R. E. CORAM
Apparatus Development Department

WHEN a radio listener hears two programs instead of one, he is, quite properly, annoyed. And when the unwanted program persists in spite of careful tuning his attitude toward the interfering station is far from cordial. The broadcasting station which operates on an authorized carrier of 600 kilocycles and then for good measure supplements this by sending out its program on 1200 and 1800 kilocycles is offering a kind of good measure of which broadcasting is in no present need. The accompanying chart shows a group of broadcasting frequencies spaced at intervals of 10 kilocycles and also shows the positions occupied on the frequency scale by their second harmonics. With the advent of more and more powerful broadcasting stations, the troublesome interference caused by carrier wave harmonics will increase unless particular care is bestowed upon their suppression.

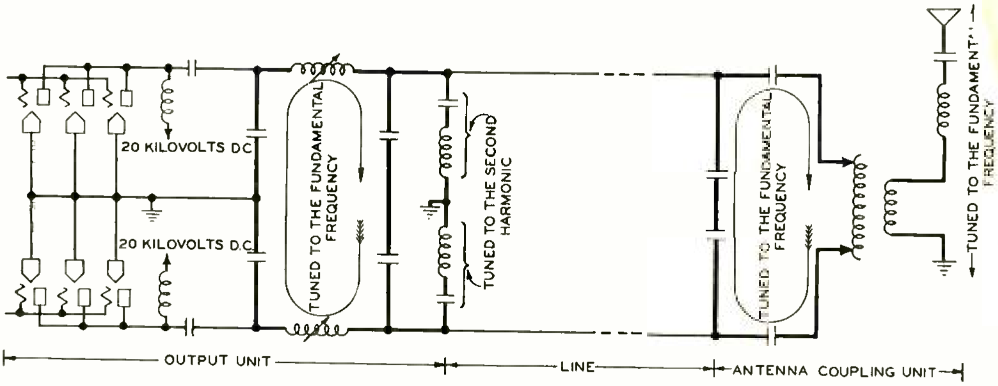


Usually the best way to get out of trouble is to avoid getting into it. In regard to the harmonic waves of broadcasting, this dictum, however, does not apply. It is not practicable to operate a transmitter in such a manner that no harmonics of its carrier wave will be produced. A transmitter free from harmonics would, in a sense, be an electrical analogue of the familiar tuning fork. The tuning fork probably comes as close to producing a pure tone—that is, a tone free from harmonics—as any of the more familiar sounding bodies. Large power output, however, is not one of the requirements of a tuning fork in its usual applications. Accordingly the tuning fork is operated over that part of its input-versus-output curve which is practically a straight line. However, the characteristic of the oscillator of a broadcasting transmitter is sharply bent within its useful operating range. It follows from this fact that any but the feeblest excitation of the radio oscillator generates harmonic waves as well as the fundamental.

Since broadcasting transmitters are necessarily expensive, good engineering economy lies rather in the direction of overloading than of underloading them. This necessarily presupposes the copious generation of harmonics of carrier waves. The designer of broadcasting equipment must, therefore, devise some scheme for by-passing and suppressing these harmonics whose production he cannot economically prevent.

The problem of freeing the authorized carrier of a broadcasting station of its harmonics bears a certain resemblance to the purification of a chemical compound. Ordinarily, a purity of 80 to 95 per cent can be readily and cheaply attained. To carry this to 99 per cent costs considerably more and to carry it to 99.9 per cent, many times as much. A reduction of harmonic radiation to zero is naturally far from practicable. The extent to which the purification is carried out is now left largely to the designers of the radio transmitter, and they look upon it as an economic balance between the job that they would like to do and the cost of the equipment that can be justified. The more powerful the broadcasting transmitter, the more important becomes the problem of attenuating its harmonics, and the greater the care which must be bestowed upon its harmonic filters.

In this respect, as in many others, 3XN, the latest broadcasting development of our Laboratories, marks a new level of attainment. The transmitter has a power input into the antenna system of 50 kilowatts for the carrier wave alone, and the instantaneous peak power during the broadcasting of a program may reach 200 kilowatts. That is enough power to meet the requirements of a village of over a hundred houses, and yet with all that power in the carrier wave, the amount of the second harmonic allowed to escape would not light the tiniest incandescent lamp made. To be exact, it is less than .005 watt and represents about one-ten-millionth of the power of the carrier wave.



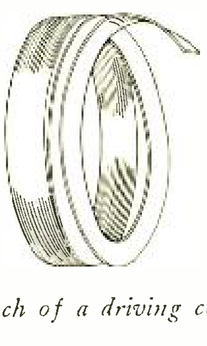
Output circuits of the Fifty-kilowatt Transmitter

The output circuit of the transmitter, with its coils and condensers, constitutes a labyrinth that brings very nearly complete destruction to the harmonics although it lets the carrier pass unhindered. Its operation is similar in principle to that of the electric filter which can separate currents of certain frequencies from currents of other frequencies. The harmonic-suppressing circuits are a sort of filter which wastes away in heat the undesired currents instead of allowing them to escape to spoil DX and short-wave reception.

An Efficient Driving Coil for Loud Speakers

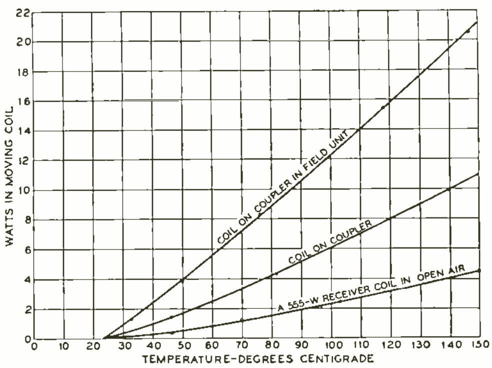
By A. L. THURAS
Research Department

THE high efficiency and quality obtained by the No. 555 loud-speaking receiver,* and the large acoustic power which it is capable of radiating without distortion, are due in considerable measure to a driving coil† of novel form. This coil is a single layer of aluminum ribbon, weighing about one-sixtieth of an ounce. Wound on edge, the wider faces of the turns are adjacent, and are cemented together by the insulation so firmly that the coil can withstand an alternating force of seven pounds. This type of construction serves several purposes. The voltage between adjacent turns is low: hence thin insulation may be used and the effect of distributed capacity is lessened. Wire of rectangular instead of circular cross-section gives a higher space-factor; together with the omission of any supporting framework, this makes possible a smaller air-gap and higher magnetic flux-density.



Sketch of a driving coil

Heat dissipation is an important factor in loud speakers designed to handle large powers. A test was made of a coil first in the open air where it was found capable of dissipating four watts at a temperature of 150 degrees C. Attached to a diaphragm, the coil could dissipate eleven watts, and when finally placed in its operating position in the air-gap it could dissipate twenty-one watts. Radiation across the air-gap is thus seen to play an important part in carrying off the heat; in this connection, a small air-gap has additional importance. The metal of the winding is continuous from the interior to the surface; this contributes to adequate cooling and



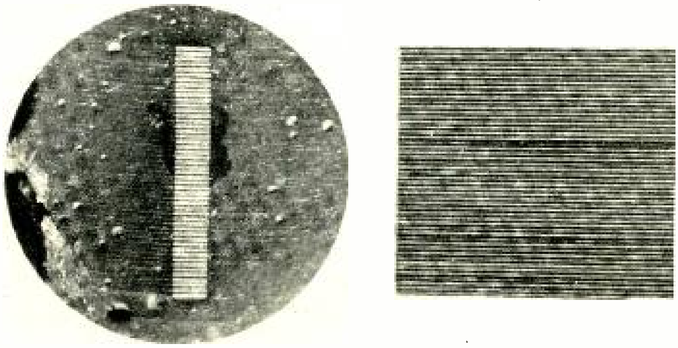
Temperature rise of a moving coil of the 555-W receiver

* Bell Laboratories Record, *May*, 1928.
† *For suggestions and development in the design and making of these coils the author is indebted to L. N. Hampton, R. O. Mercner and J. L. Mathison.*

lessens considerably the danger of warping the coil under heavy input.

Lightness of the moving system, due to its simplicity and its use of aluminum, has increased the response at high frequencies and so has improved the characteristic curve. Further improvement follows from the lack of weight in the coil, which otherwise might resonate with the stiffness of various parts of the diaphragm.

First developed for use in scientific instruments to measure acoustic impedances, coils of this type, like many another research device, are now finding application in a number of fields. What was intended to measure the dynamic characteristics of vibrating structures now finds itself launching the exhortations of the politicians or crashing out the drums and brasses of the jazz bands.



A micro-photograph of an actual coil. Left, cross-section of a coil mounted in sealing wax. Right, side view of a straightened section of coil. Both are enlarged about fifteen times. Uniformity of the winding and thickness of the insulation are evident. The curved edges of the ribbon prevent short-circuits which might be caused by rough handling

Dr. H. D. Arnold

At a meeting of the Board of Directors of City Trusts (City of Philadelphia), July 17, 1928, upon the recommendation of its Advisory Committee, there was awarded to H. D. Arnold the John Scott Medal, Certificate and Premium of $1000 for the "development of the three-electrode high-vacuum tube."

THE many friends and business associates of Dr. Arnold are highly gratified to learn that the Directors of City Trusts have awarded to him the John Scott Medal and accompanying premium for the "development of the high-vacuum three-electrode thermionic tube." As a close associate of Dr. Arnold's for seventeen years I should appreciate the privilege of saying a few words to the readers of the RECORD regarding him and concerning his work which has signally contributed to the whole field of communication as well as to related fields.

Dr. Arnold took his undergraduate work at Wesleyan, following this at the same institution by one year of graduate research on electric arcs under Professor W. G. Cady. After receiving his Master's degree in 1907, he went to the University of Chicago on a fellowship and worked under Dr. R. A. Millikan.

In 1910 the American Telephone and Telegraph Company, which had been gradually extending the length of its long distance circuits, had undertaken to solve the problem of transcontinental telephony. To establish such a service economically, it was recognized, a telephone repeater certainly greatly improved over anything then available but more probably operating on an entirely different principle was necessary. Appreciating that the field of electron-discharge phenomena offered very substantial possibilities of affording a solution of the repeater problem, Dr. F. B. Jewett wrote to Professor Millikan, recognized even then as preeminent in this field of physics, and asked him if he could recommend a man to undertake the development of electron-discharge repeaters. It is not, I trust, a breach of confidence to quote from Professor Millikan's letter to Dr. Jewett, saying that he had a man

> who is taking his degree this fall, so that he could go into the employ of the telephone company, if you can make arrangements with him right away. His name is H. D. Arnold; I have had intimate association with him ever since 1907; I regard him as one of the ablest men whose research work I have ever directed and whom I had in classes, and also I know him intimately as a man of the highest character in every particular, and a man who would be satisfactory for the purpose you have in mind; * * *

How well Professor Millikan's choice has been justified the John Scott Medal award is but one evidence.

Arrangements having been completed, Dr. Arnold entered the Engineering Department of the Western Electric Company in January,

1911. After a brief review of certain aspects of the telephone repeater problem, he turned his attention to the development of a suitable repeater element. He first directed his efforts to devices employing a mercury arc and by July, 1912, he had produced a repeater element employing a mercury arc. This repeater was used commercially to a limited extent.

Quite promptly, however, Dr. Arnold's attention was called to the "audion" of Dr. Lee DeForest, one of the most interesting and important inventions in modern electrical art. Although at that time a very crude instrument incapable of being used as a repeater in the telephone plant, Dr. Arnold recognized the possibilities inherent in this instrument and with the full concurrence and support of those responsible for the long toll-line program, he undertook the development which, starting on the basis of De Forest's three-electrode audion, resulted in the production of the modern three-electrode high-vacuum thermionic tube. This tube is adaptable to a wide range of purposes and was specifically adapted by him to commercial use in long distance wire and radio communication.

Speaking more specifically, Dr. Arnold's contributions may be listed as: first, the appreciation of the necessity of a high vacuum, and the development and application of methods for obtaining such a vacuum; second, the recognition of the existence and the importance of the space-charge effect of electrons in such a high-vacuum device, and the calculation of the magnitude of this effect and methods for its adaptation to commercial purposes; third, the development of the theories as to and means for obtaining proper physical constants for the tube in the way of input and output impedances and amplifying ratios; and fourth, the adaptation of tubes involving these newly developed principles to the telephonic problem of long-distance wire telephony and also of radio telephony. He developed designs for these tubes and methods for their manufacture such that they could be reproduced with accuracy and that dependable and interchangeable tubes could be made to meet the telephonic requirements of reliability and ease of maintenance. This work included not only the development of principles as to the spatial relations of the mechanical parts of the tubes but the development, under his immediate direction and at his suggestion, of an oxide-coated filament as a source of electrons within the tube.

The principles which he thus developed have since been further applied and extended but he himself individually was concerned with the first commercial application to wire and radio telephony of the tubes which he had developed. The vacuum tubes for transcontinental line operation met line tests in July, 1914, and public service early in 1915. Other tubes he developed to meet the problems of radio transmission; and these served as generators, modulators, amplifiers and detectors in radio transmission on April 4, 1915, from Montauk, Long Island, to Wilmington, Delaware, and later in the year in transmission from Arlington to Honolulu and Paris, and to other points.

To give any adequate picture of the present-day use of the high-vacuum tube, even in the wire communication plants of the world, would carry me far beyond any space the Editor would permit me. In a word, however, this instrumentality has made commercially possible the rapidly expanding toll-cable network which today includes the cities of the Atlantic seaboard and the cities of the middle west extending even into the south and southwest. One needs no prophetic insight to see practically the whole of the United States, not to mention adjacent territory, included in a great cable network. In Europe likewise, all of western Europe including the British Isles is being linked together by a comprehensive network of toll cables, made possible by this same instrumentality. Open-wire lines too have been made more effective by the use of the high-vacuum tube either as a voice-frequency repeater or by the use of the carrier method which is itself made commercially feasible by the vacuum tube. The modern loaded high-speed submarine cable also owes its debt to the high-vacuum tube which most readily permits full advantage to be taken of the possibilities inherent in this type of cable.

In concluding, that the reader may not be left with an unbalanced picture of Dr. Arnold's technical contributions, it is but fair to point out that while the development of the high-vacuum tube and its earlier applications were largely the results of his personal work or of work done under his close direction, as the research activities of the Bell System broadened his responsibilities were likewise broadened in scope with corresponding increase in staff for whose work he was responsible. Under his efficient direction, not to mention his very definite contribution of ideas, fundamental research work upon many phases of the communication art has been carried on. These have notably advanced the whole telephone art both wire and radio; they have made available new methods in land wire telegraphy; in submarine cable telegraphy they have furnished a new type of cable with appropriately modified methods of operation; they have given new methods of recording sounds, making possible improved phonograph records and making practical the so-called talking movie; and finally, not to extend the statement further, this work finds more or less direct application to the problem of those with impaired hearing.

E. H. Colpitts

News Notes

Dr. Jewett delivered the Edgar Marburg Lecture on June 27 before the A. S. T. M. Convention at Atlantic City, his subject being "Some Research Problems Involved in Transatlantic Telephony."

Three new members from the Laboratories have recently been elected by Edward J. Hall Chapter, Telephone Pioneers of America. They are D. T. May, R. T. Staples and W. V. Thompson, all of the Apparatus Development Department.

Fifteen naval officers were entertained in the Laboratories by members of the technical staff concerned with radio engineering, under the direction of O. M. Glunt and E. L. Nelson. These men were afforded an opportunity to visit the Whippany radio station on July 16, and the next day, under the direction of W. Wilson and A. A. Oswald, they visited the radio laboratories at Cliffwood and Deal Beach. All of the officers in the group are this year finishing graduate courses at Annapolis.

P. Norton attended the June 27 session of the A. S. T. M. Convention at Atlantic City.

Apparatus Development

Among those in attendance at the Annual A. S. T. M. meeting at Atlantic City during the week of June 25 were W. Fondiller, F. F. Lucas, H. N. VanDeusen, W. J. Shackelton, E. Montchyk, J. R. Townsend, J. M. Wilson, C. H. Greenall and H. A. Anderson.

H. N. VanDeusen, R. M. Burns and W. A. Boyd, with W. G. Freeman of the Development and Research Department, visited dial offices in Omaha and Chicago during the week of July 9 to inspect equipment from the standpoint of materials.

I. V. Williams visited the Service Machine Company at Elizabeth on June 26 in connection with the use of malleable iron in ladder brakes for central offices.

L. B. Cooke spent several days in Johnstown, Pennsylvania, making modifications and adjustments in the power line carrier system of the Associated Gas and Electric Company.

H. M. Stoller visited the Western Electric shop at Philadelphia to test transformers for control motors of talking moving picture apparatus.

J. J. Kuhn made a survey of the Atlantic City Convention Hall, particularly in regard to the Public Address System to be installed there.

H. Broadwell inspected precision interrupters for testing step-by-step switches in Reading, Pennsylvania, on June 14.

O. F. Forsberg and H. W. Goff visited Hawthorne during the week of June 18 in connection with new developments on terminal strips and dials.

J. N. Reynolds and H. F. Dobbin were in Hawthorne during the week of July 2 for conferences on dial system apparatus.

V. F. Bohman visited Albany on July 6 to observe the operation of step-by-step switches installed there.

CONSIDERABLE THOUGHT is being given at this time to the extended use of die-cast parts for substation apparatus. In this connection A. F. Gilson and H. T. Martin, with E. V. Reigle of Hawthorne, visited the plant of the Precision Die Casting Corporation at Syracuse on June 19. From their experience in making castings as well as in development of dies, officials of this company gave our engineers much valuable information.

A. K. ASTER addressed the Visual Education Department of the National Educational Association at its convention in Minneapolis on July 5, his subject being "Looking Into the Future Through Electrical Eyes."

D. H. NEWMAN made a survey for the installation of a one-kilowatt broadcasting equipment for the Richmond Development Corporation in Roanoke, Virginia, after which he supervised the installation of a 105-B equipment for the *Chicago Daily News* at Elmhurst, Illinois. In Chicago, he made inspections of the stations of the Moody Bible Institute and the Radiophone Broadcasting Corporation, and in Pittsburgh, inspected the Gimbel Brothers' radio station.

H. S. PRICE visited Cincinnati in connection with work preliminary to the installation of the 50-kilowatt broadcasting equipment for the Crosley Radio Corporation. He also inspected the radio station of the Edison Electric Illuminating Company in Boston.

W. L. TIERNEY is supervising the first installation of a crystal-controlled oscillator unit of Western Electric manufacture at KFI, Earle C. Anthony's station in Los Angeles. He will also supervise the installation of a 106-A broadcasting equipment for Nichols and Warinner at Long Beach and a 105-C equipment for the Western Broadcasting Company of Los Angeles.

THE ARTICLE by J. R. Townsend on Strength Tests of Telephone Materials which appeared in the RECORD for December, 1927, was reprinted in the July number of *Instruments*.

RESEARCH

A. R. KEMP attended the Colloid Symposium held at Toronto University during the week of June 11, later visiting the plant of the Northern Electric Company in Montreal. Mr. Kemp visited the Simplex Wire Cable Company at Boston on June 27 and 28 in connection with developments in rubber covered wire.

C. J. DAVISSON has been invited to present a paper at this year's meeting of the British Association for the Advancement of Science on the work which he and L. H. Germer have been doing on the scattering of electrons by crystals. The meeting will be held in Glasgow from September 5 to 12. While abroad Mr. Davisson will visit laboratories in Scotland and England.

HARVEY FLETCHER attended meetings of the American Federation of Organizations for the Hard of Hearing at St. Louis from June 18 to 22, and at a meeting of the Board of Managers was elected President of the Federation, to hold office for two years beginning in June, 1929. While in Minnesota earlier in the month, Dr. Fletcher visited the Mayo Clinic at Rochester as the guest of Dr. Sheard, head of research in physics.

J. B. KELLY attended a meeting of the American Federation of Organizations for the Hard of Hearing held in Cleveland, demonstrating the 4-A audiometer, and lecturing on the methods of testing the hard of hearing to a group of teachers who are studying speech reading.

H. E. Ives was a guest of George Eastman at the demonstration of colored moving pictures held July 30 at Rochester.

C. F. Keller visited the Philadelphia Instrument Shop on June 19, in connection with the production of a testing set for operators' instruments.

A. Melhose and A. D. Dowd have returned from the Azores, and A. B. Newell and M. B. Kerr from Emden, Germany, after making tests on the New York-Azores-Emden submarine telegraph cable.

E. G. Mayer returned June 29 from a two months' stay at Hawthorne, where he made studies in the standardization of analytical chemical procedure.

J. A. Lee visited the plant of the Northern Electric Company at Montreal on June 13 and 14. On June 29 Mr. Lee attended a meeting of the American Society for Testing Materials at Atlantic City.

J. F. Wentz left for Key West, Florida, on July 2 to make measurements on telephone cables.

A. L. Johnsrud lectured on television before the summer session of the University of Minnesota at Minneapolis on July 23.

Systems Development

J. Meszar spent several days at the Cleveland Toll Office in connection with tests on No. 3 toll switchboard equipment.

R. C. Hersh and E. C. Blessing have made tests on Type B carrier telegraph repeaters at Elmira, New York.

T. A. Jones is in the far west, making studies of static interference on open wire telegraph lines.

R. W. Harper and J. V. Moran spent several days in Washington, D. C., discussing the introduction of the panel system into that city.

J. G. Walsh visited Syracuse in connection with step-by-step equipment.

L. J. Bowne made tests on P. B. X. equipment in Albany.

R. E. Noble and I. W. Brown visited repeater stations at Richmond, Virginia, and Henderson, Norlina and Durham, North Carolina.

R. H. Miller visited Detroit on June 13 in connection with the new toll equipment now in process for that city.

F. T. Meyer attended the cutover of the new dial system offices in Albany on June 23.

J. G. Ferguson and H. D. Bruhn visited the first commercial installation of a 740-A P.B.X., on an estate near Detroit, Michigan.

W. F. Malone is now in Key West, Florida, and Havana, Cuba, in connection with the installation of additional telegraph facilities over the Key West-Havana cable.

C. Borgmann visited the Stromberg-Carlson factory at Rochester during the latter part of June.

R. P. Jutson visited Fort Wayne, Sault Ste. Marie and Detroit, in connection with studies of small automatic power plants.

L. A. O'Brien leaves for England about August 8 to supervise the installation of two-way type A picture transmission sets at London and Manchester for the *London Daily Express*. Since July 23 he has been testing the sets at the Philadelphia Instrument Shop with F. G. Gardner and M. A. Byers of Long Lines, who will accompany him on the installation trip. The group, under Mr. O'Brien's direction, will supervise the work of installation, carry out the operating tests, and train the customer's operators. Mr. O'Brien visited England March 21 to May 8 for an engineering survey of the project, and at that time arranged with engineers of the British Post Office for the circuit to be used.

Outside Plant Development

C. D. Hocker, F. F. Farnsworth and D. T. Sharpe conducted cable fireproofing tests at Whippany on July 9.

E. M. Honan was in Boston from June 27 to 29 in connection with the development of wire testing facilities.

C. S. Gordon, C. D. Hocker, E. M. Honan and F. F. Farnsworth attended the A. S. T. M. Convention at Atlantic City during the latter part of June.

C. H. Klein visited Pittsburgh on July 3 to conduct development studies on metal products.

B. A. Merrick made several trips to Phillipsburg, New Jersey, in connection with development studies on linemen's climbers.

Patent

In company with patent attorneys of the Western Electric Company, J. G. Roberts made a visit of inspection to the Hawthorne Works during the week of July 9.

J. G. Roberts visited Montreal, Quebec, and Akron, Ohio, in connection with patent matters. G. M. Campbell visited Philadelphia, and J. F. McEneany visited Washington for the same purpose.

During March, April, May and June, patents were awarded to the following:

W. J. Adams
A. S. Bertels
B. G. Bjornson
J. Blanchard
D. G. Blattner
O. E. Buckley (3)
H. A. Burgess
A. A. Clokey
S. T. Curran
A. M. Curtis (2)
H. F. Dodge
G. W. Elmen
J. F. Farrington (2)
J. C. Field
H. Fletcher
J. W. Foley
W. Fondiller
C. B. Fowler (2)
M. E. Fultz
J. C. Gabriel
J. O. Gargan
W. S. Gorton
C. W. Green
A. Haddock
H. C. Harrison
R. V. L. Hartley (2)
W. H. Harvey
R. A. Heising (4)
E. T. Hoch
F. A. Hoyt
H. E. Ives (2)
W. C. Jones
W. C. Jordan
W. A. Knoop
G. A. Locke
M. B. Long
F. K. Low
C. W. Lucek (2)
G. R. Lum
D. MacKenzie
E. C. Manderfeld
R. C. Mathes
E. D. Mead
C. R. Moore
E. R. Morton (5)
W. E. Mougey
E. C. Mueller
P. B. Murphy (2)
E. L. Norton
A. A. Oswald (4)
E. Peterson
W. A. Phelps
A. Raynsford
J. C. Schelleng
E. E. Schumacher (2)
O. A. Shann
H. M. Stoller (5)
D. M. Terry
G. Thompson
G. M. Thurston
H. W. Ulrich
H. Vaderson
W. Whitney
S. B. Williams

Inspection Engineering

During the latter part of June and the early part of July, meetings were held at Pittsburgh, Philadelphia and Washington to inaugurate review conferences in connection with Field Engineering work. Representatives from the Telephone Company Engineering Departments, Western Electric Company Distributing Houses and Installation Department were present. G. D. Edwards, A. G. Dalton, R. J. Nossaman and W. K. St. Clair were the representatives of the Laboratories.

E. G. D. Paterson visited the plant of the Ohio Seamless Tubing Company at Shelby, Ohio, and that of the National Fireproofing Company at Aultman, Ohio, to observe methods of manufacture and quality control of steel tubing and vitrified clay conduit.

R. M. Moody attended a regular survey conference on cable terminals at Hawthorne during the week of June 18. The following week O. S. Markuson attended a similar conference on lead covered cable. R. M. Moody and H. C. Cunningham attended a survey conference at Kearny during the week of July 9 on inspection methods for relays.

T. L. Oliver has been appointed Field Engineer in the territory of the Southern Bell Telephone and Telegraph Company with headquarters at Atlanta, Georgia. R. J. Nossaman visited Atlanta during the week of July 2 to introduce Mr. Oliver in this territory.

J. A. St. Clair, formerly in charge of the Atlanta headquarters, will take charge of the Field Engineering work in the territory of the Pacific Telephone and Telegraph Company, with headquarters in San Francisco.

General Staff

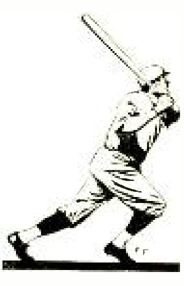
On the afternoon of June 20, S. P. Grace addressed a group of executives and supervisors of the New York Telephone Company in their auditorium on the work and developments of the Laboratories.

Mr. Grace visited the Hawthorne works during the week of July 9.

A. E. Waight, formerly an instrument maker in the Model Shop, died on June 30. He entered the Western Electric Company in 1899, and was retired last year. At the time of his retirement Mr. Waight was entrusted with the adjustment of micrometers and other measuring devices, a field in which his skill and care proved exceedingly valuable.

Club Notes

The Laboratories' team in the Bell System League did not play any of its regular scheduled games in June due to the great number of rainy days. Games were scheduled for June 5, 19 and 29, but have all been postponed on account of wet grounds. At the present time the team representing the Laboratories is in second place and has an excellent chance of winning the National League Championship and having the opportunity to take part in the post-season championship series with the winner in the American League. A Spalding trophy will be given to the winner in each league and the team winning the post-season series will receive prizes valued at one hundred and fifty dollars.



The Laboratories Club Interdepartmental League completed its 1928 season on Monday, July 9. The championship was won by the team representing the Telephone Systems Development Department without the loss of a game. This is the second championship which has been won by this department since the Club was organized and is due to a great extent to the excellent cooperation among the baseball players of Mr. Dixon's organization. The Ringers, a team which was composed of the baseball players from the Research Department, Commercial Department, and Apparatus Development Department, finished in second place. Each man on the winning team will receive as a prize a Parker fountain pen and a similar prize will be given to the most valuable player on each of the other teams in the league.

Music

Although the orchestra and glee club completed their scheduled weekly rehearsals early in May they plan to continue these activities during the summer months under the leadership of members of their own organizations Both groups are always glad to hear from new members and cordially invite musicians and vocalists to attend one or more of their summer rehearsals. Both organizations have completed their plans for the rehearsals which will start in October under the direction of professional leaders.

Tennis

The Bell Laboratories Club will hold its first tennis tournament during September and October of this year. All matches will be doubles and will be played at the Mammoth Courts, New York Avenue, Brooklyn, starting Saturday, September 22. All court fees will be paid by the contestants and prizes will be donated by the Club. If you plan to compete in this

tournament communicate at once with W. Kuhn, Extension 304, or D. D. Haggerty, Extension 542.

Bowling

The Laboratories Club Bowling League held its election of officers and unanimously elected the following for the 1928-29 bowling season:

General Chairman—A. F. Gilson
General Sec. Treas.—T. C. Rice

Chairman, Group A—H. C. Dieffenbach
Sec. Treas., Group A—G. B. Small

Chairman, Group B—L. G. Hoyt
Sec. Treas., Group B—T. V. Curley

Chairman, Group C—G. C. Crawford
Sec. Treas., Group C—K. M. Fetzer

Chairman, Group D—O. H. Danielson
Sec. Treas., Group D—L. H. Bachmann.

Additional information regarding the plans for the coming season will be published at a later date.

Swimming

Tickets for Brighton Beach Baths are sold by the Club for one-half the regular rate charged at the gate and the purchasing of these tickets eliminates any standing in line. The rate to the Laboratories Club members for Saturday is fifty cents and for Sundays and holidays, one dollar. The management of the baths provides handball courts, athletic field, pools for the kiddies, and many other interesting attractions which are all included in the admission fee.