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Transmission Limits of Telephone Lines

By R. V. L. HARTLEY

THE problem of increasing the usefulness of existing telephone lines has proven an attractive field for inventive effort. If there is something which inherently limits the possibilities in this direction a knowledge of it is useful, both in eliminating proposals which attempt the impossible and in estimating the possible improvement to be expected from methods which are in themselves sound. To show that such a limit exists and to give some idea of its nature and cause is the purpose of the present discussion.

To do this, let us start with a purely hypothetical telephone system in which the speech to be transmitted is first recorded by phonograph and then reproduced electrically, the resulting current being transmitted over the line. At the receiving end it is recorded electrically and reproduced as sound. Suppose now that in the operations of electrical reproduction at one end and recording at the other the machine be run at twice its normal speed. The effects of these two changes on the final operation should neutralize each other and the original speech should be heard at the receiving end. Owing to this speeding up, however, current will be on the line for only half the time normally occupied by the spoken message. If then we had a duplicate system available, a second message could be sent by it using the line for the remaining half of the time, thus apparently doubling the usefulness of the line.

Before accepting this conclusion, however, we must make sure that nothing happens to the electric currents produced at double speed that does not happen to those produced at normal speed. This brings us to the transmission properties of the line, which, of course, depend upon the type of line used. The two outstandingly different types are the loaded and the non-loaded. Structurally these differ in that a loaded line has coils inserted in series with the line wires at regular intervals. A non-loaded line, particularly a cable circuit, does not transmit the higher frequencies of the voice as well as it does the lower. In fact, the transmission falls off progressively as we go up the scale, and continues to fall off for frequencies still higher than occur in the voice. The loading coils improve the transmission of the voice frequencies and make it more uniform, at the expense of the frequencies above the voice range, which are practically not transmitted at all.

Suppose now that in our hypothetical system we are using a loaded line. Since the frequency of a sound is the number of vibrations, or cycles, per second, if we reproduce all of its vibrations in half as many seconds we double the number per second, that is the frequency. Thus instead of the frequencies of the commercially important speech sounds, all lying below about 2,600 cycles per second, they will now extend up to 5,200. But since the loaded line transmits only the frequencies of normal speech, those above 2,600 will be lost in transit, so that when at the receiving end the sound is recorded at double speed and reproduced at normal speed there will be present no frequencies above 1,300 cycles. From the standpoint of "frequency range" then we may say that the loaded line has transmitted only half the message. Thus we find that our hypothetical method of multiplexing has failed because it requires of the line that it transmit a wider range of frequencies than does the normal method of operation.

With a non-loaded open-wire line, on the other hand, the transmission falls off much less rapidly with increasing frequency, so that if it were used the frequencies up to 5,200 would all be transmitted reasonably well. Hence, with such a line two messages could be transmitted in the time normally taken for one.

We see then that the frequency range which a line is able to transmit determines how much the transmission over it can be speeded up. This suggests that frequency range is a way of measuring the commodity to be transported by a telephone system. It is not, however, the only measure, for we saw that the same message occupied double the range when it was reproduced at double speed. At the same time, its duration was halved. Thus the product of the frequency range times the duration remained unchanged. This would be true at whatever speed it was reproduced. Hence, this product is the true measure of the size of the message from a transmission standpoint.

In order to transmit any amount of "message" as measured in this way there must be available at least an equal amount of "message carrying capacity" expressed as the product of the frequency range transmitted by the line and the time the line is available.

For example, when we talk directly over a loaded line, the frequency range of the line is the same as that of the speech and the duration is the same in both cases. Hence the products are the same and the line is being used to its full capacity. When, however, we tried to double the amount of message by adding a second one having the same product as the first and kept the line product unchanged, we came to grief. What got through were the two messages, each minus half of its frequency range. The product for each was therefore halved and the total amount of transmitted message was as great as the message capacity of the line, and no greater.

If this were the only kind of line available the only way to obtain the message capacity for the second message would be to let it follow the first in the normal fashion, in which case the line time is doubled, or use a second line simultaneously with the first. In the case of the non-loaded line, however, we transmitted frequencies covering twice the range of the loaded line, so that the message capacity was twice as great, and we were able to handle twice as much message.

Although the greater frequency range of the non-loaded open-wire line gives a greater possible message capacity, the phonograph method is not a practical way of making use of it. Telephone messages must go through as they are spoken, and we are not free to delay them in the way that method would require. What is needed is to convert the speech waves instantaneously into waves whose frequencies lie in the upper part of the range transmitted by the line. Since in any such process the time of the wave on the line is the same as the duration of its corresponding message, it must have available a "line frequency range" at least as wide as that of the message. The most that can be hoped for then is to shift the frequency range of the message up the scale without altering its width.

This is exactly what is accomplished by the modulator of a carrier-telephone system. By using different carrier frequencies, different messages are moved to different parts of the available range. The line currents representing the various messages are separated into individual circuits at the receiving end, and each is restored to its original position on the frequency scale.

If ideal filters were available for separating these currents the ranges representing these various messages could be placed adjacent to each other. The sum of the frequency-range by duration products for all the messages would then be equal to the product for the line and no further improvement would be possible. Actual carrier systems then fall short of the best possible utilization of the message capacity of the line only in so far as the properties of actual filters make it necessary to leave intervals between the frequency ranges which are assigned to the various channels.

So far we have been talking only about commercial speech, the frequency range of which extends roughly from 200 to 2,600 cycles. For satisfactory broadcasting we must preserve something like twice this range. Hence a broadcasting program represents about twice as much message as does ordinary telephone speech of the same duration. Hence it requires lines of twice the message capacity. A telegraph message, on the other hand, ordinarily involves a frequency range of less than 100 cycles, and so represents a relatively small amount of message. It is for this reason that by the use of a voice-frequency carrier-telegraph system we are able to transmit ten telegraph channels over a single talking circuit.

When we come to radio, the same principles apply. Here the line is the ether, the frequency range of which, while large compared with that of a telephone line, nevertheless has limits. Messages have been transferred by modulation to all parts of the frequency scale from about ten thousand cycles to about twenty million cycles. Nowhere near all of this range has been utilized to its fullest capacity as yet. In fact, owing to the difficulty of removing one of the so-called side-bands at high frequencies each message is generally represented in the ether by a wave occupying twice the frequency range of the message. Also the filtering problem is more difficult than at low frequencies. This, coupled with the large effect of small percentage fluctuations in the carrier frequencies, has made it desirable to leave larger frequency-intervals between the message ranges than is done on wire lines. If economic considerations in the future justify the expense of overcoming these engineering difficulties, there is the possibility of considerable increase in the utilization of the message capacity of the ether.

In general, then, we see that the possible multiplexing of a line is limited by this fact: of the frequency-range transmitted by the line for every individual message there must be set aside enough for a long enough time so that the product of frequency-range by time is equal to a similar product determined by the nature and duration of the message. The application of this principle to the evaluation of any concrete proposal for increasing the usefulness of any set of lines is obvious. Simply multiply, for each message which is said to be transmitted, the frequency range it occupies by its duration; and add the results for the various messages. For each line involved multiply the frequency range which it transmits by the time it is available and add the results. If the first sum exceeds the second the method is unsound. If it is less, the method may, or may not, be sound. If we assume that it is sound, then the difference between the two sums measures how far the arrangement falls short of the fullest possible utilization of the lines.

Coordinating for the Common Welfare

"No finer example exists in the world of coordinating engineering and financial resources for the common welfare than the Bell telephone system of the United States. The fundamental service requirements are obviously not those of central stations . . . On the other hand, the central station man and the transmission line builder have much to learn from the telephone engineer's broader methods of planning for future development.

"In the October issue of the Bell System Technical Journal, H. P. Charlesworth discusses "The General Engineering Problems of the Bell System" with a breadth of view well worth cultivating among electric light and power companies. The author's emphasis upon the necessity for advance planning to insure economical performance and satisfactory service, his review of the problem of building location, program scheduling, duct location and general plant anticipation, based on commercial surveys and engineering forecasts, fits admirably into the central station picture.

"The electric light and power industry can wisely take a leaf from the engineering book of the telephone company as it feels its way into larger territorial usefulness.

From an editorial comment in the Electrical World

Installing Radio Broadcasting Equipment

By P. H. Evans

When a corporate body, religious organization or individual comes to the conclusion that greater publicity and good will can be obtained from operating a high grade broadcasting station than can accrue from the extensive use of posters on bill-boards, unread tracts or circular letters, there generally results a contract with the Graybar Electric Company for radio-telephone broadcasting equipment of the Western Electric Company.

To the Laboratories this means that an engineer will be required to visit the purchaser, answer technical questions relative to the equipment or its installation which arise in the purchaser's mind, consider the available sites and discuss special operating features, including remote pick-up, which the purchaser has in mind. Upon the return of the engineer to New York, recommendations and drawings are prepared for the Graybar Electric Company to send to their customer. These give our ideas on the location of the antenna and station quarters, the proper height and spacing of towers, the correct dimensions of the antenna and the layout of the

The studio of Station KFI, Los Angeles

Station WSB is on the roof of the Atlanta-Biltmore Hotel

rooms and equipment; in other words, the best use of the space at our disposal. One problem that usually comes up is the design of control circuits which will provide for any special operating features. Generally considerable apparatus is required in addition to the standard equipment because of the use of special control-circuits, pick-up points outside the studios and the separation of the studios from the transmitting equipment. Apparatus to meet these requirements must be specified.

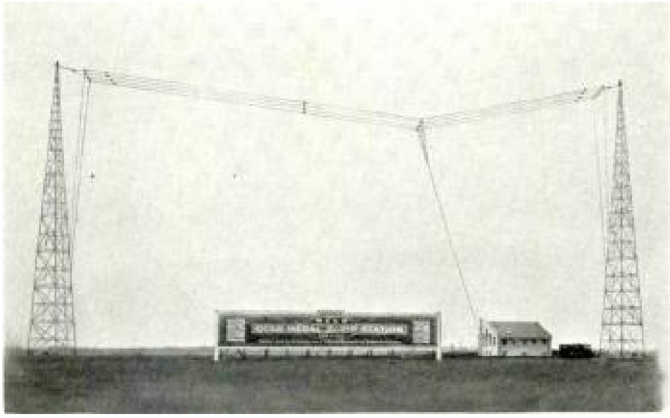
Sometimes the purchaser desires to locate his station on the roof of an existing building. Before plans can proceed on this basis, the purchaser must consult his architect to determine whether or not the building is capable of supporting the towers recommended. During the first three years of broadcasting building-top locations were the rule, but with the advent of higher power many prefer a location in a sparsely settled area well outside the city limits. This involves the selection of a site where good roads, reliable power circuits and high-grade telephone lines are accessible. It generally means the design and construction of a special building for the broadcasting station—sometimes including studios but generally with studios located elsewhere.

The purchaser, of course, makes his own contracts with the various suppliers and tradesmen for all materials and work involved in the erection of antenna supports, the alteration of existing buildings or the construction of new ones, the acoustic treatment of the studios, the decorating and furnishing of quarters and the electrical work on the apparatus and ground systems.

Our recommendations are complete enough so that the purchaser can finish the installation with the exception of testing and adjusting the equipment for best operation, but it is rarely ever done this way. Questions arise which the purchaser wishes to discuss with the supervising engineer. Neither he nor his contractors have anything in their past experience to guide them in the installation of radio equipment. He is always anxious to get on the air at the earliest possible moment and as soon as he hears his equipment has been shipped he generally announces the opening date and sends for the engineer. This sets the fireworks off. Ordinarily, his conception of the time or work involved in completing the installation and getting it in good operating condition is too optimistic. If the equipment arrives in the morning, he is certain it ought to be connected up and on the air that evening. It makes no difference whether or not the antenna is up or the studios finished. Radio is impossible and therefore nothing can be impossible to one who understands radio!

Edwin M. Spence, its director, and a day's mail at Station WPG

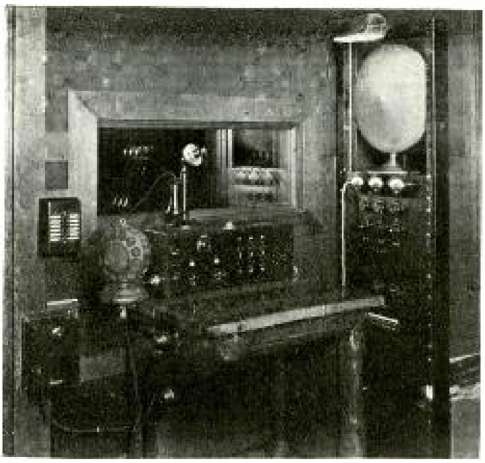
The last few days before the "opening" no one sleeps; and the last day no one eats. To one who has not been through a "rush-opening" it is impossible to appreciate the grip an event of this sort has on the purchaser from the president to the janitor. Strange as it may seem, a station generally opens on schedule whether this date was reasonable or unreasonable. Many are the exciting tales that can be told of our races with time. In one case, the engineer was unable to give the O.K. to go ahead until five minutes before the scheduled time. In another case trouble developed due to inadequate time for testing. An operator discovered that by push-



The Washburn-Crosby broadcasting station, WCCO ing a particular conduit the trouble disappeared and the program was finished with the operator holding the conduit in the required position. It developed later that in laying the floor the carpenter had cracked a condulet. This introduced radio frequencies into the microphone circuit and produced radio-frequency "singing". In another case the motor for the motor-generator set was shipped separately, and lost in transit. To open the station on schedule it was necessary to borrow a motor locally, belt it to the generators and operate in this fashion until another motor could be shipped by the manufacturer.

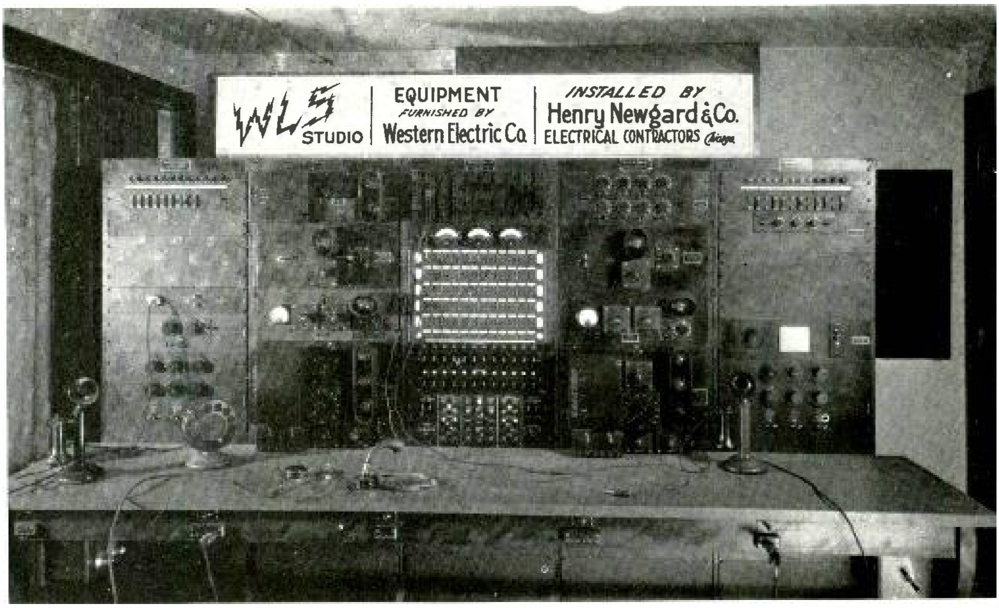
Probably the most difficult things to do in a broadcasting installation are to obtain an efficient ground and to shield adequately the speech circuits from the field of the antenna. To obtain the former, it is necessary to install an extensive ground-network and bond to it every metal object of any size in the field of the antenna. To obtain the latter, it is necessary to use lead-covered wire in metal conduit bonded to the ground system at frequent intervals.

The pictures illustrate typical building-top and ground installations as well as a typical control-room and announcer's booth. One of the most interesting features of the installation is the control room. Other parts of the installation are generally pretty much standardized but no two of the larger jobs are alike in respect to the control equipment. One purchaser uses an announcer's booth and wants to be able to shift back and forth from the booth to any studio or remote pick-up point. Another purchaser does not want the announcer's booth but wants to be able to start a program number in one studio and for the next number to go into another studio where he will be able to control both studios. One purchaser wants a special announcer's microphone; another prefers to announce from the program microphone. Some want loud speakers in the studios not in use which will be automatically cut off when the microphone in that studio is in use. Some want automatic change in the studio illumination; others prefer signal lights. Some want duplicate amplifying channels which will enable the program director to hold auditions in one studio while broadcasting from another, and so it goes.



Announcer's booth at Station WOC, Davenport

The picture of the control room of WLS shows an equipment which is typical of the present day trend. On the second and fourth bays are located two separate amplifying channels. One 9-A and two 18-B amplifiers together with a volume-control panel are located on these bays and drive cone-type loud-speakers in the artists' reception room, the public reception room, the executive offices, and the studio not in use. On the first and fifth bays are "mixing" panels which provide for an announcer's microphone and two program microphones in each studio. Above the mixing



Control Equipment of Station WLS

panel on the fifth bay is an eight-channel microphone-switching panel which will connect to the amplifiers the microphones at the various pick-up points in the hotel. On the third bay are the normal jacks for the various amplifiers and panels on the other bays, the lines to the various pick-up points about Chicago, the lines to the transmitting station at Crete, and the signal lamps and control switches. In this installation it is possible to control the microphones in the studio or control-room from any of three points. In fact they may be put on at one control point and removed at another. The illumination in each studio is automatically increased when the program microphones in that studio are turned on, and the cone loud-speakers are automatically turned off when either the announcer's or the program microphone is turned on.

Experience extending over the last four years including one hundred and fifteen installations indicates that the average installation, including preliminary survey, office engineering, supervision of the installation, training of the operating personnel and engineering service after the station is in operation, requires the services of an engineer for a total of approximately three months' time. This, of course, is split up among several trips and distributed over a considerable period of time; and several different engineers may take part in one installation.

THE FIRST WOMAN TELEPHONE OPERATOR

ALL of us who are interested in the development of electrical communication, know the story of the invention of the telephone. Likewise, we know the stories of the men who were prominent in its invention and commercial development. But who was the pioneer of the women, who to-day play such an important part in the efficient functioning of the huge telephone plant?

In the very early days all of the operators were boys or young men. Not until September, 1878, two and one-half years after the telephone was invented, did a woman operator enter upon the scene. Miss Emma M. Nutt, now of 84 Browne Street, Brookline, Massachusetts, is that woman. She was employed by Mr. N. W. Lillie, the manager of the Boston Exchange.

The first of many hundred thousand

A letter from Miss Nutt was received some time ago by W. L. Richards, Consulting Historian, which gives her memories of the early days:

The switchboard extended nearly the length of the room, leaving a space between that and the operators' tables for the switchman who answered the calls. He stood in front of the switchboard with several long cords hanging around his neck, on each end of which was a plug, and another cord in his hand with a plug on one end and a telephone on the other. When a subscriber rang, the switchman would plug in and using the telephone as both receiver and transmitter ascertain the name of the party wanted (numbers were not used at that time). He would then take two of the cords from around his neck and connect the party calling and the party called with the operators' table. There were seven tables arranged in a line in front of the switchboard one after the other, A, B, C, D, E, F and G, and a chair at each table. The tables were similar to an old style sewing machine. On each there were two black walnut stands or standards, on one of which was a Blake transmitter in a walnut box, on the other the telephone. Along the front of the table there were I think three pairs of nickel strips and a cord to which was attached a jack with a push button on it. Directly in front of the operator, resting on the back of her table was placed a list board on which was tacked a paper nearly the size of the board on which were the names of the subscribers. They were written in red and blue pencil. The bells corresponded with the colors. Numbers were not in use then. The switchman called out the names of the party called and calling; also on which strips he had put them. The operator, after she had called the subscriber, was supposed to listen to the conversation as much as possible to make sure the message went through correctly. If they could not hear distinctly or get the message correctly, the operator was supposed to transmit. When they had finished, she notified the switchman, and he disconnected the lines.

The Microscope as an Industrial Tool

By Anna K. Marshall

THE microscope has long been a valuable tool in the industrial world and in our Laboratories we have some of the best equipment in existence for microscopic studies. These studies are conducted by the Metallographic Department, a subdivision of the General Development Laboratories, and its personnel is frequently consulted in the solution of problems where microscopic analysis is desirable. Awaiting its attention there are always problems involving metals, wood, porcelain, rubber, paper and in fact any material that might be used in products manufactured for the Bell System.

Metals as is well known are made up of crystals, or grains, which are not as a rule large enough to be seen unless magnified by the microscope. To reveal the nature of this granular structure, a piece of the metal is first flattened and then so highly polished that not even a tiny scratch is left upon its surface. Then an acid is applied to its surface to etch it and thus bring out the design of the grains of the metal. Each metal has a definite crystalline form. Some acids will etch one metal and not another. Some metals are highly resistant to acids; others respond quickly to their action. Each metal is a problem in itself. Nearly every known metal is brought into the laboratory for study: the base metals such as iron, steel, brass, lead; the precious metals such

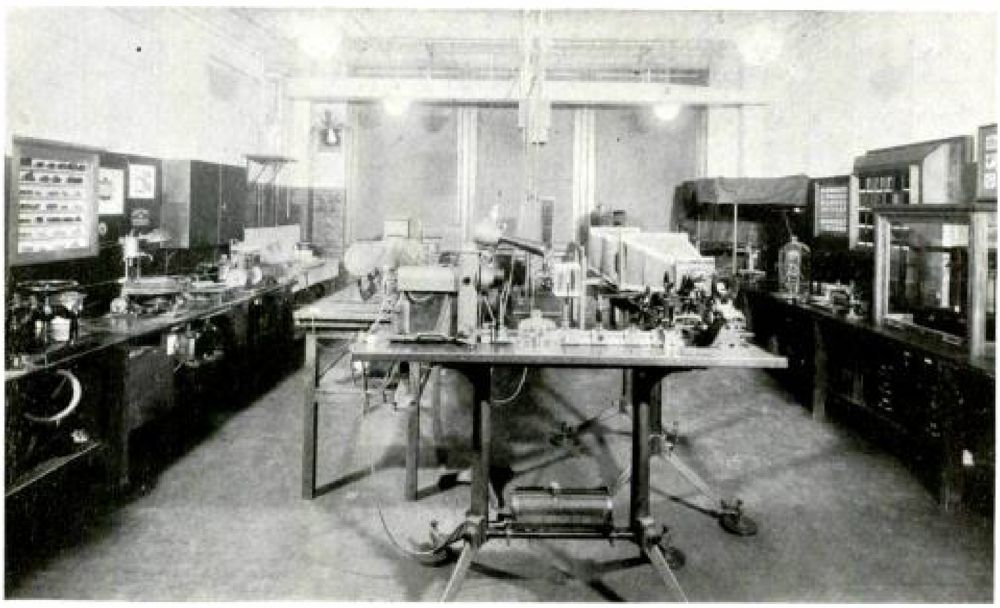


Fig. 1. A general view of the microscopical laboratory.

as gold and platinum; and even the rare earths such as cerium and lanthanum.

What could one wish to know about

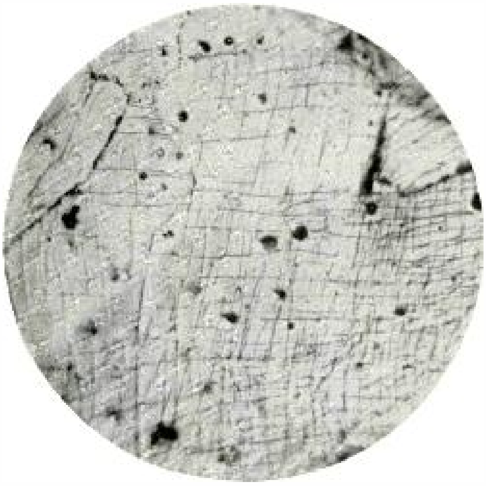


Fig. 2. The network of fine lines is the result of severe mechanical stress on this piece of lead. Magnified 200 times

[*Note: Where magnifications are stated they are those of the original photomicrograph, not of the engraved reproduction*]

these various metals, and what is the practical application of the knowledge gained by such studies? The most graphic answer to such questions is the citation of few specific problems.

One day two men came in, heavily burdened by a motor, a certain portion of which was in question—was it made of iron or of steel? It took a bit of persuasion to get them to part with an unbelievably small piece of the part under suspicion. This specimen was duly prepared and the structure upon examination was found to be cast iron.

A break had occurred in the steel wire which was used in a telephone line for crossing a river in a single long span. Previous to installation the wire had passed the usual necessary rigid inspection tests. After the break occurred a sample was cut at the point of the break for microscopic diagnosis of the trouble. The steel was found to be what is commercially known as "dirty steel"; that is, it contained at the point of fracture large slags which are factors of weakness in steel wire.

By carrying a piece of metal through certain temperature changes, its crystalline structure can be wholly rearranged. For example, a metal heated to its thermal critical range will form a new set of grains. This was done with a piece of lead in a furnace so arranged that the process could be watched with the microscope. At the right minute the metal was removed from the furnace, thereby showing both the old and the new sets of crystals. Under the microscope it is possible also to see how mechanical strains show up in deformations of the crystals.

Some elusive substances which refuse to reveal themselves when viewed under an ordinary microscope can be seen on a special apparatus called the

Fig. 3. The crystal structure of brass with its light and dark areas in many crystals, characteristic of this metal and known as "twinning." Magnification 85 times

ultra-microscope, whose lighting system holds the secret of its efficacy. Colloids, particles of one substance so finely dispersed in another as a medium that they are indistinguishable from the medium itself, are thus brought within the range of vision. Not only that, but they can be counted as well. Rubber latex dispersed in water shows up in a satisfactorily spectacular manner when seen by this means. Whether a substance is or is not a colloid can also be determined by studying it under the ultra-microscope.

Case-hardened tools have been examined in this laboratory. In such tools the outside must be very hard while the inside should be comparatively soft. With the aid of the microscope judgments may be made of the quality of the steel and also a determination of the thickness of the case. In one instance this case-hardened surface was found to be five ten-thousandths of an inch in thickness.

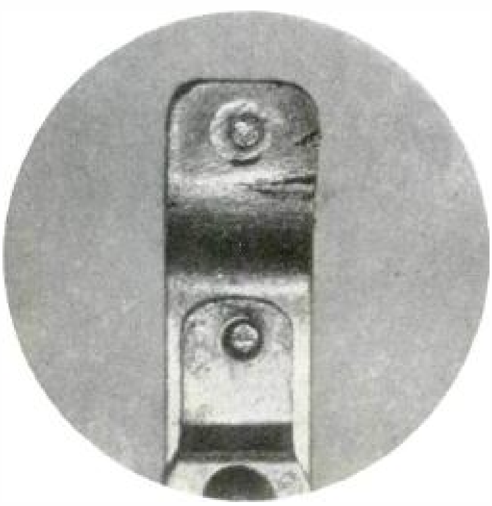


Fig. 4. Illustrating the value of photomicrography of small parts in the process of testing. Here is shown a relay contact assembly, the contacts somewhat worn. Magnification 5½ times

Another problem of analysis which frequently arises is that of paper. By using the proper methods of mounting and staining, it is possible to determine whether a paper was made of wood pulp, or of rag stock.

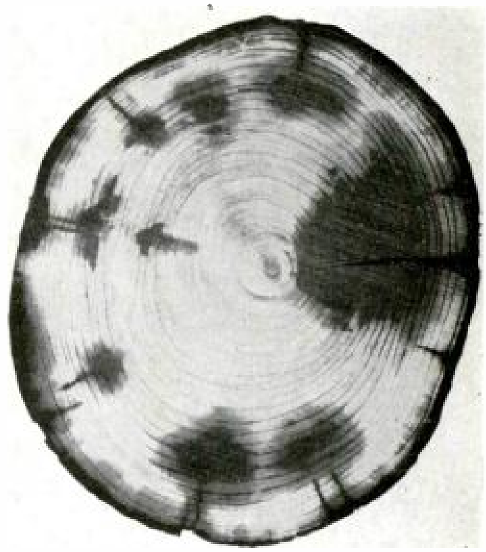


Fig. 5. A Juniper telephone pole showing unusual penetration of creosote oil.

Probably to most of us rubber is merely rubber. But to industry, certain qualities are essential, depending upon the uses to which the material will be put. For examination a uniform section of the rubber is cut thin enough to be transparent. When the ordinary illumination for microscopic vision does not bring out its structure clearly, a special illumination is used. This gives a dark background in which the rubber particles appear gleaming white and clear. The size of the particles and their distribution are important in such a study.

Telephone poles are subject to various troubles which the microscope makes evident. It may be that they have not been adequately impregnated with creosote oil, and a fungus gets a foothold, causing decay. Or the creosote oil may have penetrated the wood in a peculiar manner. What is the cause of the oil flowing in one direction when it should supposedly go only in the opposite direction? or what is the name of the fungus that has attacked a sturdy pole? or of what kind of wood is a particular sample? By means of a very accurate apparatus, called a microtome, it is possible to cut a section of wood to any desired thickness. Usually .0002 to .0006 inches is sufficient to bring out clearly the structure of the wood, the penetration of the oil, and the life struggle of the fungus within the wood cells. A test was once made in the laboratory to prove the powers of an impregnating wax but it was found that the fungus rather liked that wax, and grew luxuriantly, nestling close to the "fatal" germicide.

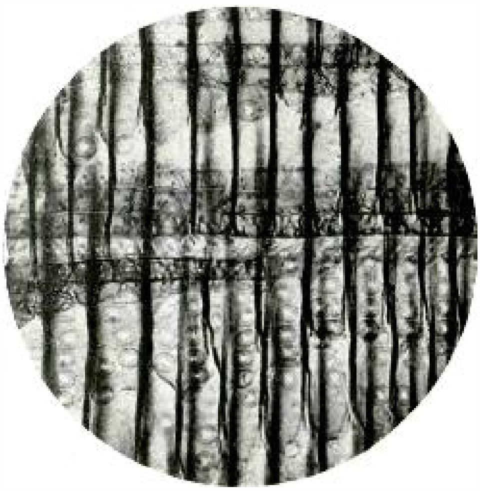


Fig. 6. Radial section of yellow pine. Magnification 125 times

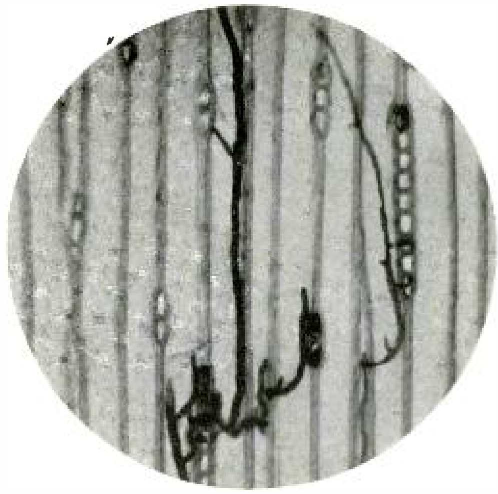


Fig. 7. Mycelial threads of a sap-staining fungus in a pine pole. Magnification 230 times.

In the technique of photomicrography, it is necessary to use colored filters, either to cut out certain colors of the spectrum or to let them pass through. The color chosen for any given subject is determined by what is to be brought out in its picture. Each specimen has its own colors. If contrast is desired, one filter is used; if detail, another filter is chosen. These gelatin filters are very long-lived, yet even with the most careful use they will sometimes deteriorate. They may look the same as usual, yet give poor results. By means of a spectroscope a periodic check-up is

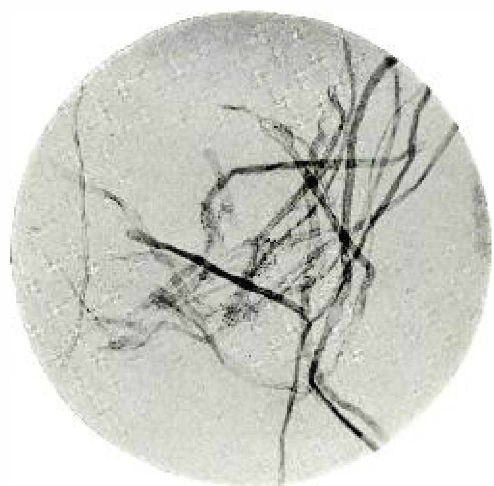


Fig. 8. The structure of paper fibers revealed at a magnification of 103 times

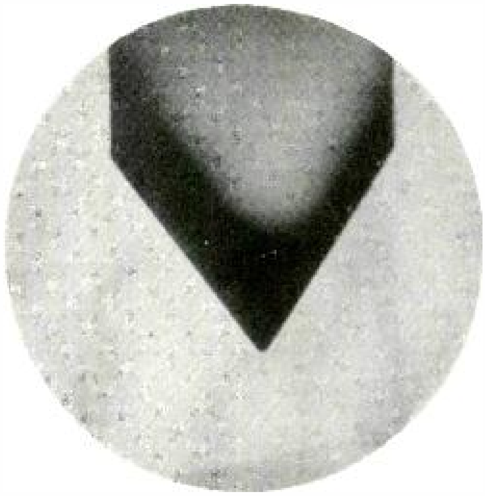


Fig. 9. A sapphire phonograph recording needle enlarged to facilitate the measurement of its angles

made on the laboratory's filters. If a red filter, for instance, allows any of the green portion of the spectrum to pass through, it would no longer be an efficient filter.

In the microscope the objective is the lens nearest the object under examination. As it is an integral part and highly important especially in photomicrography, it should always be at its best. In case it gives a hazy picture, it is subjected to a rigid test on a little device called an "apertom-

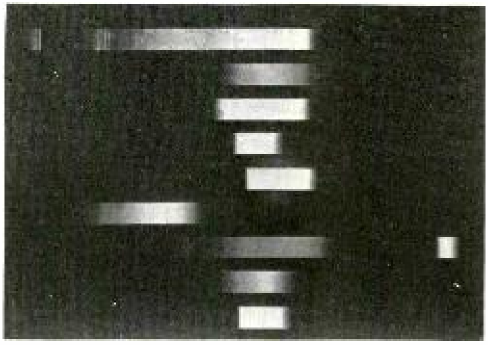


Fig. 10. The effect of light filters when used with a particular photographic plate is determined by photographing the spectrum of the light transmitted by the filter

eter" on which the numerical aperture is determined. And as further evidence of its good qualities, or otherwise, it is also tested on an Abbe's test-plate to see whether its color fringes are what they should be for that type of an objective. Because all this work requires the greatest of accuracy, the apparatus for accomplishing these results must always be kept in the best of condition.

Where formerly scientists relied upon written notes or drawings for records it is coming to be more and more the practice to prove the truth of claimed observations by the "see-

Fig. 11. When lead is heated to its critical point, small crystals are superseded by large ones. This picture, at a magnification of 200, shows both kinds

ing is believing" method of photographs. Plain black and white pictures, however, are not sufficient. It is sometimes better to show up a subject in its true colors! The simplest and most direct route to attain results is to photograph the specimen upon a specially prepared plate, which when developed will reproduce accurately the colors of the specimen. If the specimen is transparent and colorless, it may be given color by using polarized light.

It was formerly thought that a magnification of 1,500 diameters is sufficiently high to obtain all that can be had from a subject, due to the limitations of the lens system of a microscope. Early attempts to photograph at higher magnifications seemed to confirm this idea because the pictures up to this limit were clear, but beyond that point usually became more and more hazy, indistinct and muddy, and correspondingly of no value. In this laboratory, however, crisp and clear pictures at higher magnifications have been made and are constantly being made; the best ones being 2,400, 3,500 and so on up to 6,000 diameters, although a magnification of 9,000 also brings out clearly many a point otherwise unresolved. Thus far no satisfactorily crisp pictures have been obtained at higher magnifications, although it is possible to see much fine detail at 12,500.

The True Perspective of Research

We of the Bell System take pride in acknowledging our indebtedness to science and in tracing in electrical communication some of our most noteworthy results of a practical nature to their ancestry in the solutions of problems of physics or chemistry which were underaken without utilitarian purpose in the quest of a deeper understanding of nature.

Considered on a broad basis, there are good grounds for believing that all industries benefit about equally from the progress of science. We conceive of our social organism as having a nervous system and various organs, each performing functions which are coordinated as to character and scope with those of the others. In this organism there is a spontaneous distribution of the economic benefits of science, which reach practically all industries in proportion to their size and importance. This is true, I believe, notwithstanding the fact that on the surface the benefits of science appear to influence certain industries more conspicuously than others.

As we meet with added success in turning scientific discoveries to practical account, we are confronted with a strong temptation to seek knowledge because it is useful, and not simply for the sake of knowledge itself. We are thus in danger of losing the true perspective, for it becomes increasingly easy to pass from seeking knowledge because it is useful to seeking what we may consider, from a priori reasons, to be useful knowledge. No touchstone has been vouchsafed us by which we can predetermine even approximately the usefulness of the scientific discoveries which are to be made in the quest of a broader knowledge.

From an address by F. B. Jewett before the A.A.A.S. (Kansas City, December 30, 1925) on the Interdependence of Engineering, Industrial Research, and Research without Utilitarian Objective.

Telephone Signalling

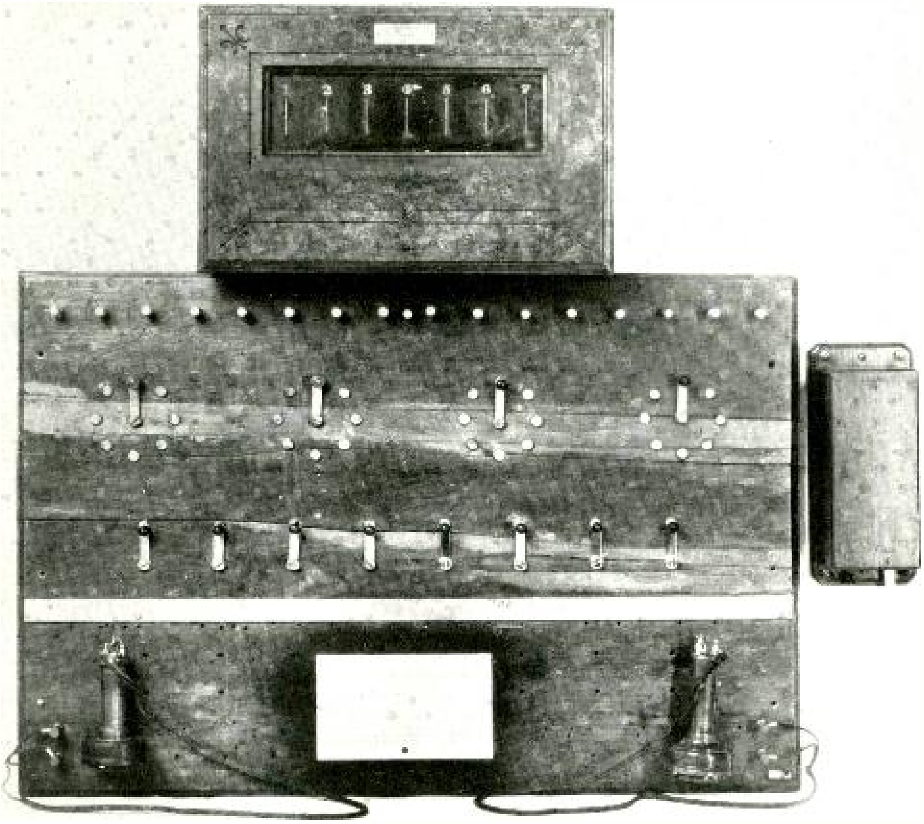
SOME early developments in telephone signalling were described in the January issue of the RECORD. The systems there described were those used to attract the attention of the subscriber, and all involved audible signals. Another class of signals was alluded to in this article: namely, those employed for the information and guidance of the operator. With a few exceptions such as night-alarm bells and line-busy signals these are visual rather than audible.

In order to secure a connection with the line which he desires to call, a subscriber must first attract the attention of the central-office operator. The first and oldest method is used practically always with magneto switchboards and is in the form of an electromagnetic annunciator or drop. There are various types of drops but all depend upon the same fundamental principle. In the simplest form a magnet is included in the line circuit and its armature can release a latch which normally holds a shutter or drop in a raised position. When the subscriber operates his hand generator the magnet is energized and its armature moves, thereby releasing the shutter, which falls by gravity.

The operator thus summoned plugs in and establishes the talking circuits. In modern practice the act of inserting the plug serves automatically to restore the shutter to its normal position, either by energizing a restoring magnet or mechanically by the pressure of the plug against the shutter

To relieve the operator of the necessity of opening the listening key from time to time to ascertain if a conversation is finished, it is desirable to have a signal which will inform the operator when a conversation is concluded. To do this, the same method is employed as is used in making the call. In magneto boards it is the practice for one or both subscribers to send a clear-out signal; that is, "ring off," by turning their hand-generators after hanging up the receiver. This causes the clearing-out drop shutter to fall and informs the operator that the conversation is over.

In common-battery switchboards it is standard practice to use tiny incandescent lamps for signalling purposes. The line lamp is the primary signal and corresponds to the magneto drop, except that its operation is automatic and requires no manual action on the part of the subscriber other than removing the receiver from the hook. As the receiver is removed, the hook springs upward and completes the connection which operates a relay known as a line relay. A relay of this sort is associated with each subscriber's line and when operated passes current into a lamp which is individually associated with its line. The operator completes the call as in the magneto board. Information that the conversation is closed is likewise automatic. As soon as the receiver is replaced on the hook, cutting off current



Meriden, Connecticut, Switchboard, built in 1878
This was one of the earliest boards. Watson's buzzer is mounted at the right

in the subscriber's line, it releases a relay which lights a so-called "supervisory lamp." This informs the operator that the line is no longer being used.

The incandescent lamp signals have several noteworthy advantages over the electro-mechanical methods employed in the magneto board. In the first place, they are capable of attracting the attention of an operator with more certainty than the drop shutter. Then they are entirely free from mechanical complication; they are more compact; they are entirely automatic in their operation; and they are easily replaced when destroyed. Also, by the use of various colored glass, they may be utilized to indicate different kinds of information.

Supervisory Signals

A number of signal lamps termed "supervisory lamps" are associated with the cord which the operator uses to connect two telephones. These play a very important part in the efficient operation of the board. The operator is able to supervise the condition of the lines during the time that they are connected for conversation without having to listen in or disturb the service in any way. The operator makes each connection between two subscribers with a flexible cord ending in two plugs which may be fitted into the jacks on the switchboard at which each subscriber's line terminates. When the operator inserts the answering plug of this cord the line relay is automatically cut off from the line and the supervisory circuit is brought in. The called number is ascertained and the calling plug inserted. A supervisory lamp immediately lights and remains so until the called subscriber removes his receiver. Thus the operator is informed when a called subscriber answers, without having to listen in for the response; and when the conversation is closed and both receivers are replaced, the supervisory lamps corresponding to both circuits light and direct the operator to disconnect the cord circuit. If only one of the lamps lights the operator knows that one subscriber is still on the line and desires further service. It will be noted that a lighted lamp is always a signal that something is to be done; when the circuit needs no attention no lamps are lighted.

Inter-office Signalling

Simple switchboards only have so far been considered. But in large communities there are several central offices and one call may have to go through two or more. Therefore, in order to facilitate proper communication, there must be provision for the necessary calling between operators of different offices.

In the simplest inter-office communication the operator at one office reaches the operator at the called office by direct ringing. This is known as the "ring-down" method. The first operator receives the number from the subscriber and connects her cord circuit with the proper trunk. A trunk is a line connecting two telephone switchboards. She then rings just as she would ring a subscriber and the called operator responds. The latter operator ascertains the number desired and completes the connection. Supervision is maintained by clearing-out ringing.

This method is too slow for metropolitan systems and more efficient schemes for the handling of inter-office calls have been developed. In multiple-office exchanges there are two types of switchboards in each office. One series, known as "A" boards, receives all incoming calls from subscribers: and the other, or "B" boards, receives incoming calls from other offices. When a call goes through two offices it is received by the "A-operator" in the first office and the called line is connected by the "B-operator" in the other office.

The ring-down scheme of inter-office calling was followed by the "order-wire" method, which is now the standard of most metropolitan exchanges. In this plan the various offices of a local system are inter-connected by trunk lines. On the keyboard of each A-operator, there is a call-wire button for each office to which, or through which, she may have occasion to establish connections. To call any office the operator merely depresses the proper button, connecting her headset with that of a B-operator in the called office. To this B-operator the A-operator tells the number of the called subscriber. The B-operator assigns a trunk and the A-operator connects her calling subscriber's line with that trunk while the B-operator connects the called subscriber. Ringing of the subscriber's bell starts automatically and continues intermittently until he lifts his receiver. This action operates a "lock-up" relay which remains locked until the trunk cord is taken down, and prevents the ringing from starting again when the called subscriber replaces his receiver at the end of the conversation.

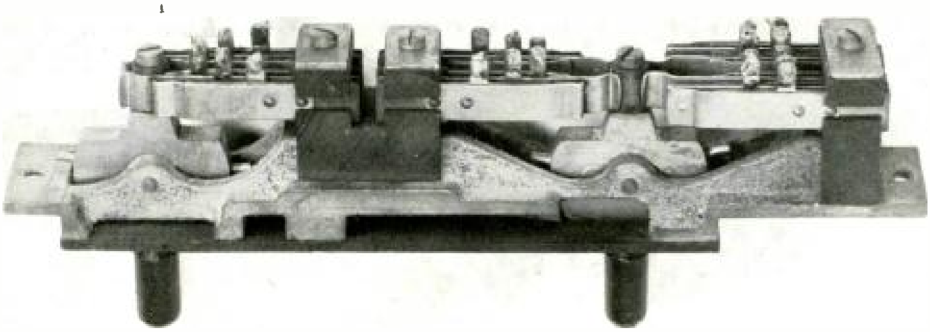
Another system of inter-office communication is known as straightforward trunking. It employs the inter-office trunk as an order wire for the conversation which is to take place over it. When the A-operator receives a number from the calling subscriber, she tests the jacks of the trunk group to the proper office and plugs into an idle one. This lights a lamp in front of the B-operator at the called office. If the B-operator is busy the lamp burns steadily, but as soon as she is free her headset is automatically connected to the particular trunk and the lamp flashes, thus indicating the cord which is to have her attention. An audible signal then automatically notifies the A-operator that "B" is ready to hear the called number. As the B-operator replies "right" she makes the proper connection. And as she plugs in, her headset is automatically disconnected and connected to the next trunk which awaits attention.

The particular system just described is "automatic listening"; other forms are also used. In "key listening" the operator presses a key opposite the lighted lamp of a trunk circuit; in "jack listening" she inserts the trunk plug into a special jack and receives the called number, after which she plugs into the desired line jack.

Busy Signals

Mention has been made of busy tests. These result in signals from the apparatus rather than from another operator. When the operator in testing for a free line finds a busy one, a small current flows through the sleeve of the jack to the tip of the plug and through one winding of her cord circuit to ground. She then hears a click. If the line is idle, there is no voltage-to-ground on the jack sleeve, and no click is heard. If no other circuits are available (as for instance auxiliary subscribers' lines bearing consecutive numbers*) the operator gives a busy report. Between operators the busy report is by signal, the

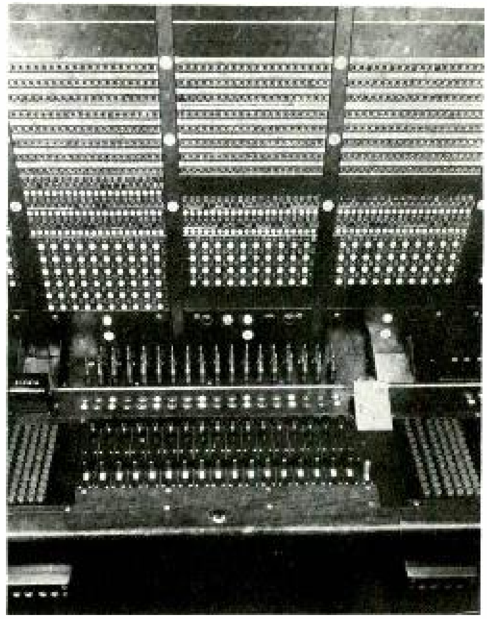
**The Bell Laboratories have twenty-four such lines from the Chelsea central office, in addition to a considerable number of non-consecutively numbered lines.*



Details of an early form of ringing and listening key

B-operator inserting the trunk plug into one of a group of jacks marked "Busy." This connects the trunk through to interrupter contacts on the ringing machine which alternately grounds both wires and connects them across a source of tone. At the "A" board this flashes the supervisory lamp; to the subscriber it gives an "interrupted tone" which is generally recognized as the "busy signal."

When a line is out of order it is "plugged up" by a cord to indicate trouble. On the sleeve wire of this cord, in addition to "battery" to hold up the cut-off relay and prevent a steady signal at the line lamp, is a tone which can be picked up by any operator who tests the line with the tip of a plug. An A-operator will report the line out of order; a B-operator will treat it as "busy" and plug the trunk into the "busy back."



One "A" operator's position of a common-battery switchboard

Toll-Line Signals

From the equipment standpoint it is impossible to make a sharp division between toll and local trunking. The operating method and circuits to be used between two points depends on the volume of business and the speed desired. Most toll circuits are ring-down; between the larger centers, as New York-Philadelphia, order wires are used; and a few special methods are used on long routes, such as New York-Chicago. Ringing on toll lines is at twenty cycles when the pair of wires carries only the normal voice channels. When the low-frequency range of the circuit is occupied by a composite telegraph channel, ringing is at 135 cycles in order to avoid mutual interference. This frequency is too low for efficient handling in telephone repeaters; and on long circuits it is necessary to have a 135 cycle relay at alternate repeaters to transmit the ring. A comparatively recent development is the of use 1000 cycle ringing current; since this frequency is in the working range of telephone repeaters, these give sufficient amplification and no intermediate mechanical relaying is needed. Considerable simplification thus becomes possible in repeater-station circuits and in carrier-current systems.

A typical toll operator's signalling equipment consists of a two-position lever key in each cord circuit, which enables her to ring in either direction. Incoming signals are received by a suitable relay and light a lamp beside the incoming line jack. In magneto offices the signal releases a drop shutter.

At terminating offices, as distinguished from "through" offices, the circuits provide that the terminal operator can supervise the circuit through to the local calling or called subscriber. Movement of the receiver hook operates relays which light or extinguish a supervisory lamp on the keyshelf.

The busy test can be made on toll lines in the same way as on subscriber's lines by touching the tip of the plug to the sleeve of the jack. A toll line, however, handles about ten times as many calls per day as a subscriber's line, and so it is economical to simplify the busy test at the expense of a more expensive circuit. A visual busy signal is used which does away with the necessity of testing jacks to find an idle trunk. This scheme operates automatically. When the operator plugs into the jack of an idle line a relay operates to close a supervisory circuit which causes a shutter to drop at each of the multiple jacks of that trunk. This informs all the other toll operators that this particular line is in use.

Machine-Switching Signals

In a community where there are both manual and machine-switching offices, it is necessary to have a system of signalling by which a machine-switching subscriber may obtain a connection with a manual subscriber. To take care of these calls all manual offices in a community where there are both types have several positions equipped with "call indicators." With such equipment, when the subscriber dials in the regular manner, the desired number is flashed before a B-operator in the called office and she completes the connection.

Full machine switching systems, whereby a complete call is made without the assistance of an operator, are not signalling systems but more properly remote-control systems. They accomplish the selection of a desired line by means of a relay-operated mechanism in a central office. This mechanism is actuated and controlled by electrical impulses sent, or rather caused to be sent, by the acts of the calling subscriber.

In a typical successful system a series of impulses corresponds to each of the ten digits and to letters or symbols for the name of the desired central office. The subscriber dials his own connections. Each movement of the dial sends successive impulses, a particular series for each stop of the dial, over the circuit. These impulses operate the relays that cause the necessary vertical and rotary travel of the line switches, selectors, trunk repeaters, and connectors, until the calling subscriber is connected to the line of the called subscriber or to a busy-line circuit.

As for signalling, in all the systems developed the attention of the subscriber is called by a bell which is rung by the central office ringing generator. In some early cases it was necessary for the calling subscriber to operate a ringing button, but in present systems the ringing is automatic.

Telephone Train Dispatching

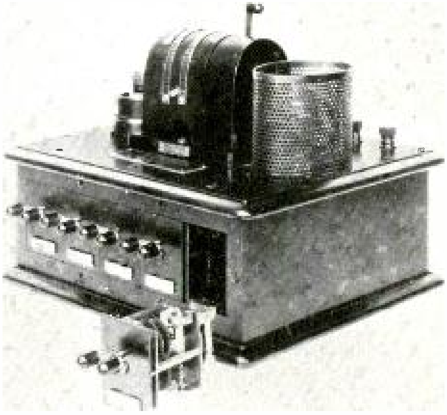
Another important field for selective signalling, and one that is of constantly increasing importance, is found in railroad train dispatching, with which many of the large railroads have equipped their most important divisions. The chief requirement of such a system is the ability to signal any one of fifty or more stations or all of them simultaneously. To accomplish this a highly specialized party-line system has been developed.

Such systems usually operate on the step-by-step principle. A typical one includes a sending key and a receiving mechanism known as the selector. There may be a code key for each station or a master key for signalling all stations. The selector consists essentially of a polar relay with a ratchet attachment so arranged that successive operations of the relay cause a contact wheel to rotate in steps. There is a separate adjustment for each station and when the contact wheel has operated over the number of steps corresponding to the code of the desired station a contact which operates a signal is made. The selector at each station is adjusted to respond both to its individual call and to the general call for all stations.

Radio-Telephone Signalling

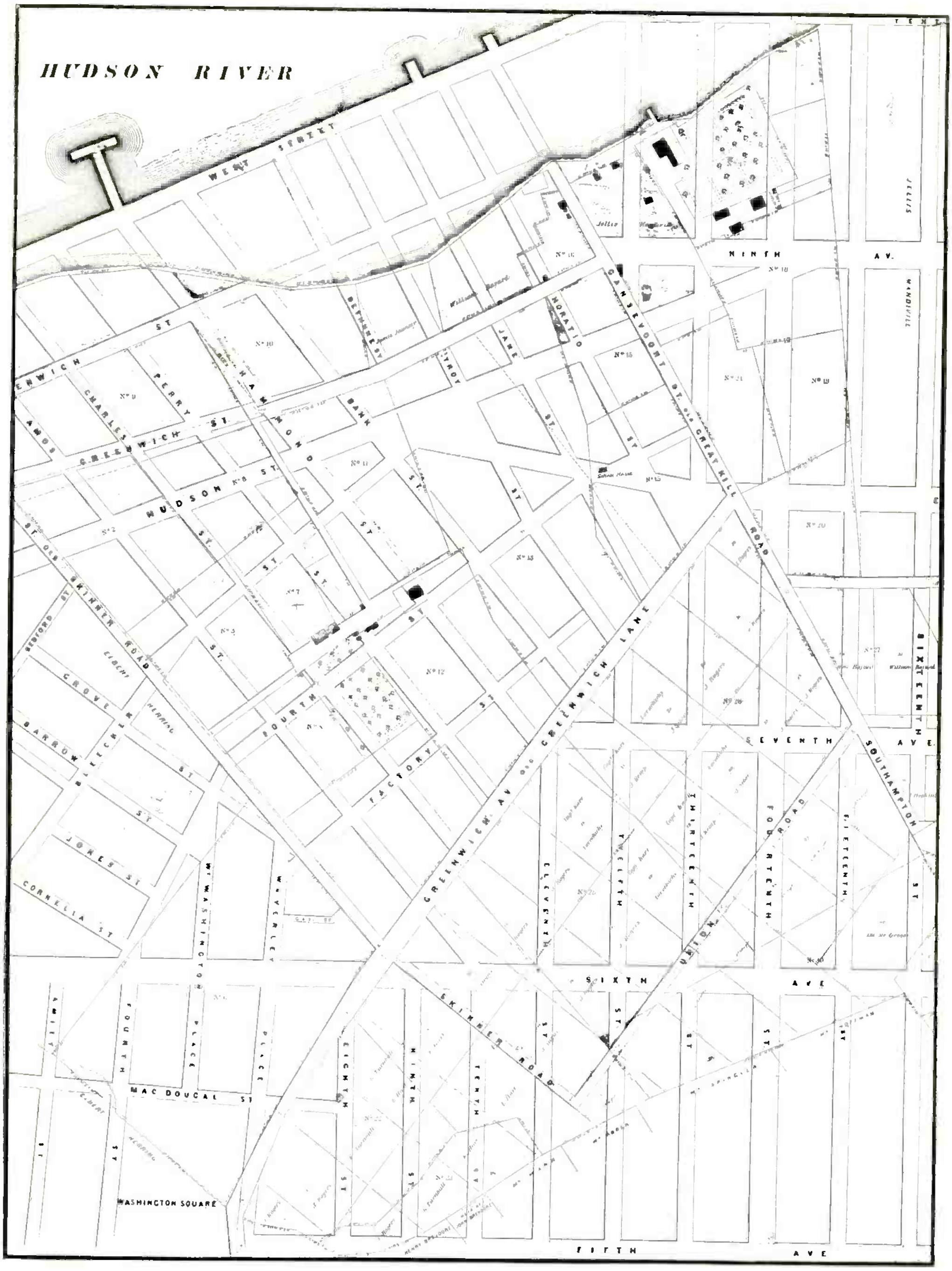
The latest chapter in telephonic signalling is being written now by its application to radio. An automatic low-frequency selective system which employs a mechanically tuned alternating-current receiving relay has been developed and has proved well adapted to operate with any type of radio receiver that is suitable for receiving speech. The outgoing signal is produced by applying to the transmitter an alternating current of a frequency within the voice range in the same way that the voice currents are applied. At the receiving station the current is rectified by a vacuum tube and applied to a sensitive direct-current relay. The operation of this relay closes a circuit through a secondary relay which operates the local signal.

Such a system is practically independent of the type of radio service, the power capacity of the radio system



Code calling equipment for radio signalling

and the wave length used. Other practical methods of selective signalling have been developed for radio services between ship and shore, and for the radio connection of police substations in metropolitan areas.



"The Sir Peter Warren Farm"

This old map of our neighborhood, dated 1864, shows not only the streets as they were in Civil War times, but the original Greenwich lanes and alleys. Sir Peter Warren, an eighteenth-century British admiral, at one time owned nearly all of this section.

The camera claims the attention of Thomas A. Watson and Mr. Craft, who are visiting the museum in company with Mr. Richards.

The original telephone of Alexander Graham Bell was fashioned by Mr. Watson with his own hands; and it was he who heard over it the first spoken words ever electrically transmitted. Many proofs of Mr. Watson's ingenuity and ability as a designer, which have been described in previous issues of the RECORD are preserved in our Museum.

His interest in design and his appreciation of the refinements of mechanical construction gave authority to his complimentary comments on the apparatus developments of today. He was much impressed by the continuing progress in our technique as evidenced by the few details of recently designed equipment which he had time to see.

His First Job

JUST before the close of the last century the telephone business, like most other industries, was considered a job for "practical" men. When Sergius P. Grace was employed by the Detroit Telephone Company as a potential wireman, soon after his graduation from the University of Michigan in 1896, he was not heralded as are the young engineers of to-day. He was introduced to his life's work by being requested to whitewash the cable vault. Mr. Grace wielded the brush while John G. Roberts, another recent graduate and now our General Patent Attorney, carried the pail.

Sergius P. Grace

Within a year Mr. Grace was Chief Engineer of the Detroit Company. This promotion was due largely to his study of electrolysis, about which very little was then known. His report on the electrolytic action which was threatening to wreck the company's underground cable and his recommendations for a remedy were submitted to the cable manufacturers and were returned with the suggestion that they be followed in all details.

His first job with the Bell System came about four years later, when he engineered the modernization to common battery of magneto exchanges in Dallas, Galveston, Houston and Fort Worth.

While Chief Engineer of the Interstate Telephone Company of New Jersey, he designed and superintended the construction of a toll-line along the banks of the old Delaware and Raritan Canal, which canal was built in the early part of the last century under the direction of his own grandfather, and was at that time considered the last word in communication facilities.

In 1903 Mr. Grace went to Pittsburgh and for ten years was Chief Engineer of the Central District and Printing Telegraph Company—now a part of the Bell Telephone Company of Pennsylvania.

Later he became connected with the New York Telephone Company. From the New York Company Mr. Grace in 1921 went to the American Telephone and Telegraph Company as Engineer of Foreign Wire Relations. In 1924 he came to West Street as Commercial Development Engineer for the Western Electric Company, his present position in the Laboratories.

Water Cooling in Radio Broadcasting

By J. O. Gargan

As long as man has endured upon this earth and as long as he shall remain there will tax his ingenuity the eternal problem of controlling heat. Always is he seeking either to have available more energy in the form of heat or to dissipate without inconvenience to himself an excess which oppresses or endangers his person or his projects. In winter he incases himself in many layers of dark insulating material to retain his own heat energy and to accept by radiation all possible contributions. "In summer quite the other way," he encourages heat losses and reflects in light-colored clothes as much brilliant heat as he may.

In the various contrivances with which he eases his physical existence he meets the eternal problem of delivering heat to one point and removing heat from another. When this problem does not intrude upon his attention it is only because the designers of the mechanism have provided automatic means for its solution or because under the conditions of operation of the contrivance the amount of heat is negligible.

The universality of the problem is commonly obscured by the formal language of thermodynamics in which it is stated. In looser terms it might be said that in the physical world no useful action is ever one hundred percent efficient. Always the action is accompanied by what is, speaking idealistically, an unnecessary amount of heat. The athlete running in a track meet finds his useful efforts to outdistance his competitors accompanied by a production of heat. The engine of an automobile can utilize but a fraction of the energy released by the exploding mixture of gasoline and air in its cylinders. The balance of this energy, as heat, becomes a source of danger to the engine and in excess of what the engine mechanism can stand it must be removed. Around the engine walls water is therefore circulated, and the heat which it thus acquires is passed on to the surround-

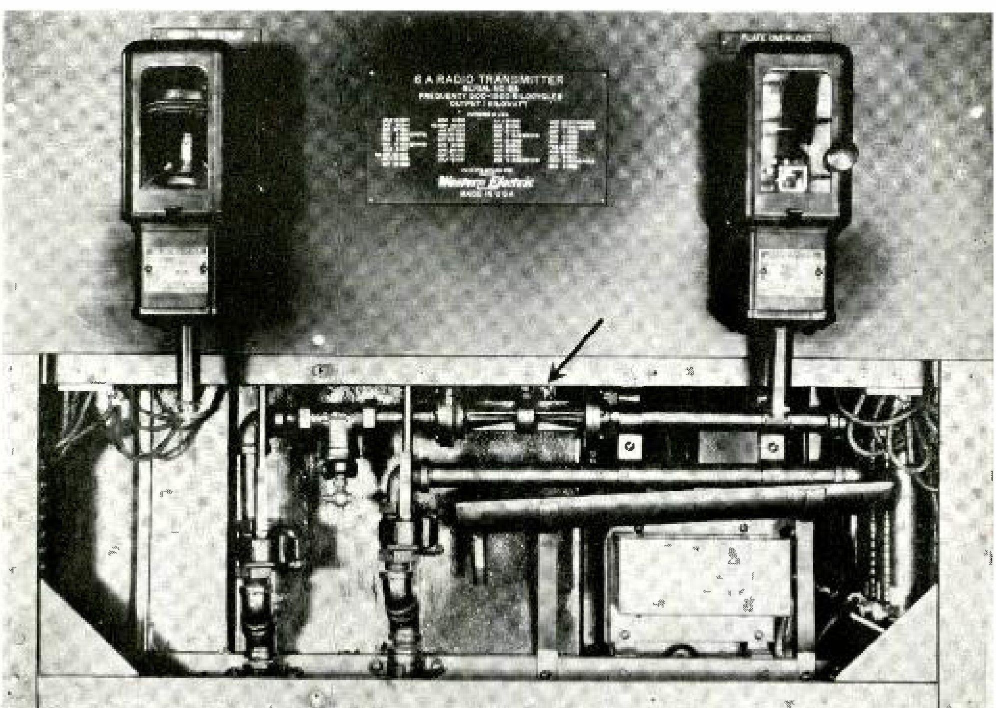
The author points out the flow-controlled relay in a 1000 watt broadcasting transmitter ing air, a portion of which is drawn through the radiator of the car.

Electronic devices are no except'on to this general principle. In the vacuum tube, electrons freed from the filament are drawn across the intervening vacuum to travel through the plate circuit and back to the filament. In this travel they accomplish their useful purpose and contribute a portion of their energy to the output circuit of the tube. Their passage through the vacuum is occasioned by a battery or generator in the plate circuit; but at the plate itself they are somewhat abruptly slowed down. Their successive impacts heat the plate just as the successive blows of a hammer heat a nail which they are driving. If this heat* is not to damage the plate and quickly destroy the tube it must be removed in some manner.

In the smaller tubes of a radio receiving set the impacts are not so numerous or severe as in the large power tubes of a transmitting station. The heat developed at the plate is easily radiated and conducted to the surrounding air and no special cooling devices need be provided. For large power the water-cooled tube was developed in our Laboratories. In this, as is generally known, the plate in the form of a metal cylinder serves as the outer wall of the vacuum chamber within which are the filament and grid. Water cooling then becomes possible in a manner essentially analogous to the cooling of the cylinder walls of a gasoline engine.

The plate of a vacuum power-tube is, of course, maintained at a high potential during the operation of the tube, and the solution of the problem

**A very considerable part of the heat liberated in the tube is, of course, developed in the filament.*

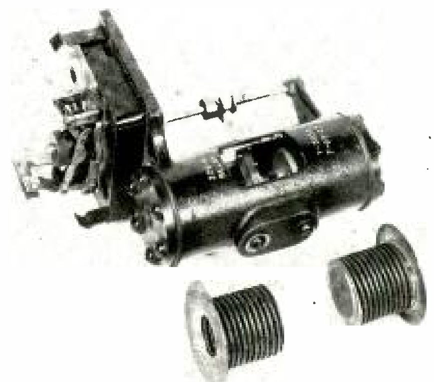


The arrow points to the venturi tube which converts flow-changes into pressure-changes of cooling the tube by water circulation is complicated by the necessity of insulating the plate from the rest of the apparatus. Long rubber tubes are therefore used to bring the cooled water to the plate and to remove the heated water to the radiator. The electrical connection to the plate from the radiator, ground and remaining apparatus is then through a long column of water. If the water is free from impurities this column serves practically as an insulator. Actually, however, the presence of impurities in the water permits a certain amount of leakage of current from the plate to ground.

Although in the electrical relations the cooling of power tubes is not analogous to the cooling of a gasoline engine, the analogy is essentially complete in the necessity for maintaining a circulation of cooling water during operation. If the tube should be operated without being cooled the plate would be severely over-heated, vapors would be produced in the tube, the vacuum would collapse, and instead of a pure electronic current between filament and plate there would be an arc which might puncture the plate and destroy the filament and tube as well. Some mechanism therefore had to be devised to protect the tubes by shutting down the transmitting apparatus in case of failure of the water supply or a stoppage of its flow through clogging.

Commercial gauges were available which indicated when the water pressure exceeded a certain amount or fell below another limitation. Pressure, however, is not the measure of satisfactory operation. It is a definite flow of water which is desired. A search was therefore made for a gauge which would measure flow directly and for a mechanism which would operate an alarm or shut down the broadcasting set in case the water flow was inadequate. A well known principle of hydrodynamics aided this search.

This is the principle of the venturi tube, which depends upon the action of a stream of water, during its flow along an otherwise uniform pipe, in passing through a short section which is constricted into a shape something like that of an hour glass. Since water is for practical purposes non-compressible, at each point along the pipe and also in the venturi water must be flowing at the same rate: that is, the same quantity must pass each point of the tube each second. Since the rate of flow is the same all along the tube, inevitably in the constricted portion the individual particles of water must be moving with greater velocity than in the remainder of the tube.



The relay itself; in the foreground are the two metal bellows

The product of the water pressure times its velocity is, to a close approximation, constant throughout the venturi nozzle. Therefore at the point of constriction where the velocity is greatest the pressure is lowest. Between any two points in the venturi there will exist, while water is flowing, a pressure difference which is a measure of the velocity of flow; and this pressure difference will be greatest between the wide part, at the end where the nozzle joins onto the otherwise uniform pipe, and the narrow throat in its middle.

In the use of the venturi two small tubes are tapped on, one at its minimum diameter, and another at its maximum diameter on the up-stream side. These tubes are connected with gauges for measuring pressure. The difference of pressure indicated at the two points becomes a measure of the velocity flow of the water. Sometimes these tapped tubes end in vertical "U's" containing mercury, and the water pressure is indicated by the difference in level of the mercury columns on the two sides of each "U".

A device incorporating such a venturi tube with mercury columns to measure the pressure difference was invented by Arthur A. Oswald and successfully used. Another solution was contained in a special valve design by Miles E. Fultz, where the valve was actuated by water flow. The improved device which is now being used and is incorporated in the Western Electric 6-A Radio Transmitter, which is part of the 106-A Radio Telephone Broadcasting Equipment (1000 watt), was a development of the writer's which followed his study of available apparatus and previous methods. It makes use of the venturi tube and operates with bellows which respond to pressure differences.

Two tubes are tapped into the venturi, one at the constriction and one up-stream. One of these tubes ends in a water-tight metal bellows located on one side of a lever. The other runs to a duplicate bellows on the opposite side of the lever. The two bellows work against each other in controlling the position of the lever. When the proper volume of water is flowing, the pressure difference in the venturi causes one bellows unit to expand and the other to contract. The lever is then so arranged that in the position in which it is held by these two bellows it closes an electrical circuit. Next the fulcrum of the lever is adjusted so that any specific decrease of flow, with the resulting change in position of the bellows, will move the lever far enough to open the electrical circuit. The opening of this circuit can then be used to operate an alarm or to shut down the broadcasting set, the latter method being the one actually employed.

This device, which protects a Western Electric broadcasting set from the loss of its tube equipment due to failure of the water cooling system, is a simple and positively acting mechanism. It allows a generous margin of variation in the flow, can be easily adjusted, has contacts which are readily accessible, and can handle currents and voltages of such magnitude as are met with in the apparatus. In addition it is of substantial construction and should last almost indefinitely.

New Telephone Systems Drafting Room

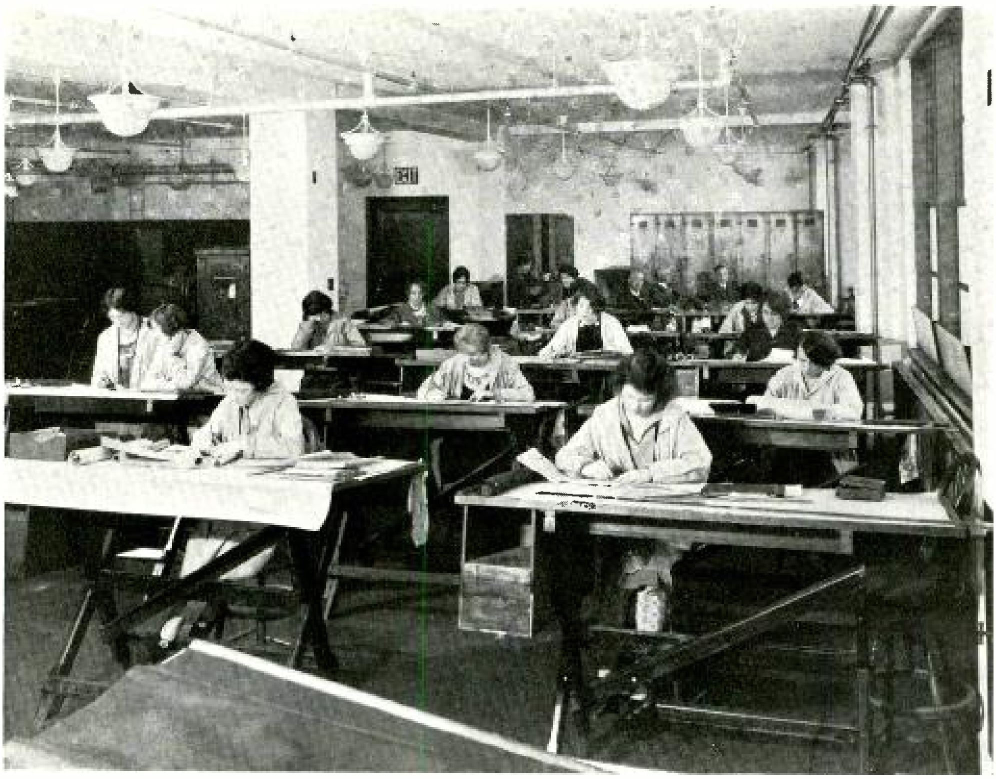
By Reinhold Petersen

The first move into our new building occurred on January 2nd, when the Equipment Drafting Group collected its three divisions from their separate locations in the older buildings into one large drafting room on the fifth floor of "Section H." The new building, with its well lighted interior, now makes it possible for our draftsmen to work in what is probably as fine a drafting room as can be found in the country.

The Equipment Drafting Organization has one hundred and thirty draftsmen who make all the equipment and circuit drawings required in our development of telephone systems. The organization consists of three main divisions.

The Circuit Division, for which Charles D. Dusheck is responsible, constructs the circuit drawings for our toll, manual, and machine-switching systems, including the manufacturing drawings of circuits required in trial-installation work. This division has a number of draftswomen, who have proven their ability to make the

The new Systems Department drafting room on the fifth floor of Section H



Another view of the new drafting room

intricate circuit schematics necessitated by our machine-switching systems. They have found this work agreeable as a change from many of the occupations open to women and have shown themselves capable "draftsmen" in every way. In this group Student Assistants, and other young draftsmen fresh from the high schools, make their first contact with modern drafting practices.

The drafting work in connection with framework, cabling, equipment, and assemblies for selector frames, switchboards, desks, power plants, and so on, is divided between two Equipment Divisions under the supervision respectively of C. A. Bolin and A. B. S. Kvaal. This work ranges from the simplest equipment and numbering drawings to complicated designs required by selector-frame and switchboard structures. The floor-plan layouts are an interesting phase of their work, involving extensive studies in order so to locate the various frames, racks and other equipment, that economical cabling and maintenance is possible. The power-plant drawings require familiarity with the practices and regulations governing commercial power-plant construction.

The drafting room is an interesting place to get an overall picture of the wide variety of engineering work carried on in our Bell Laboratories, as the younger draftsmen in their training period find themselves making drawings covering practically every phase of the Company's development work. They begin making circuit drawings for carrier systems, various toll systems, panel-machine-switching systems, new manual systems such as the No. 11 switchboard, and straightforward trunking. A plan has been set up whereby, after becoming acquainted with the various features connected with the circuit work, practical experience is given in the laboratories by laying out cables from these same circuits for laboratory tests. This enables the student draftsmen to see the use to which their drafting work is put, and at the same time familiarizes them with the mounting of the equipment and the necessary clearances. They then continue their work on equipment numbering drawings, power data sheets, and drawings for switchboard, desk and selector frame equipments; thereafter they advance to simpler designs of keyshelves, test boxes, woodwork assemblies, and the like.

After graduation from the Student Assistant Course certain of the younger draftsmen are sent into the field to do regular installation work, according to a schedule which gives them special training as to the factors governing layout of floor plans. Again entering the drafting room they are given work bringing them into contact with the more complex designs of the switchboards, frames and local cables. This plan has been found to give a comprehensive picture of those factors governing our design of central-office equipment. At present there are thirty student draftsmen on various stages of this course and several have qualified for engineering work along the lines of their training. A great many of the engineers who are contributing to the improvement of our vast communication system received their early training in the drafting rooms of the Bell System.

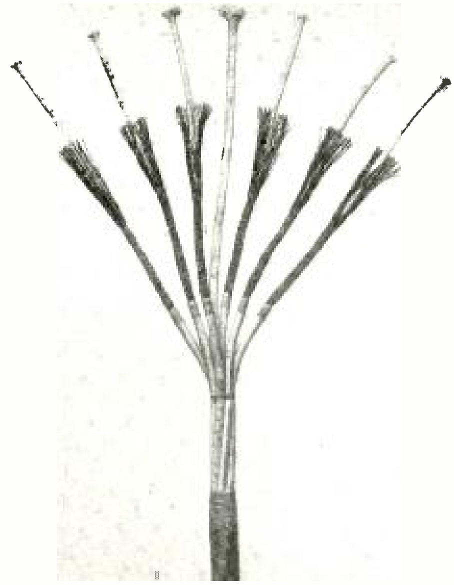
Transmission Circuits for Telephone Communication

The London Times in a recent Trade and Engineering Supplement devotes more than a column to a review of "Transmission Circuits" by K. S. Johnson. Introduced as "the achievement of a master of the subject," the reviewer states that the author has "provided every possible aid to the acquisition of the degree of mastery that the subject merits." In the course of an outline of the subject matter, attention is called to "an elucidation of the general case of networks that places Mr. Johnson in the front rank as a teacher." A compliment is paid the Bell System in the statement "at each turn of the road, specialists have been at work . . . . financial aid has been forthcoming, and the whole has been developed beyond anything that telegraph engineers dreamed of."

Stranded Conductor for High Frequency

The story of a useful design for radio-frequency currents

TEN years ago, in connection with the Arlington radio-telephone tests, which were described in the October issue of the RECORD, a special stranded conductor for an antenna coil was developed by the Laboratories and manufactured at Hawthorne. A stranded conductor was desired to reduce skin-effect resistance to the high-frequency currents. The coils were made under the direction of Carl Englund, who was at that time carrying on a general investigation of low-power-loss coils for radio use. E. B. Wheeler and H. H. Glenn were concerned with the mechanical design.



Stranded Cable with Braided Conductors for High-Frequency Currents

In the case of each cable, groups of individual conductors, insulated by enamel, were wound about a cotton-twine core; and the groups of stranded conductors thus formed were in turn twisted about another core of cotton twine to form a large cable. The operations were performed on cabling and braiding machines. In one design the individual conductors were braided around the cotton core and in the other they were spirally wrapped. The accompanying picture shows the braided cable. Coils wound of these conductors when tested at Arlington showed the designs to be effective. The coils, however, did not happen to be used in the transmission at the time the distance records were made. The braided cable was formed by six strands, each consisting of forty-eight No. 30 B & S enamel-insulated copper wires braided about a twine core. The other cable consisted of six strands, each including thirty-four No. 26 wires spiralled in parallel around a core.

In this connection an interesting development in radio design is reported in THE ELECTRICIAN (London, Nov. 20, 1925). A cable of a somewhat similar design, but involving over twenty times as many individual wires, has been constructed for the British Post Office for use in the Rugby transatlantic radio station.

Apparatus Which Makes Air a Liquid

The First of a Series of Articles on the Work Done in our Basement

By G. F. Morrison

THE manufacture of liquid air depends upon two simple principles: first, that air becomes a liquid upon being cooled to a temperature of 312 degrees Fahrenheit below zero; and second, that air cools in expansion. All that is necessary is to compress the air—providing a water-cooling system to carry away the heat generated by compression—purify it, put it into a place where it can expand and cool, and collect the liquid in bottles.

A casual glance at the liquid-air apparatus in Basement B, however, does not give the impression of so simple a process. In one room there is the four-stage compressor shown in Figure 1; in another room, the purifying tanks, final cooler, and liquefiers, shown in Figure 2. The way it all works is this:

There are four compression-cylinders and five cooling-cylinders in the compressor. Air is admitted into the first cylinder and subjected to a pressure of fifty pounds to the square inch. From there it passes through the first

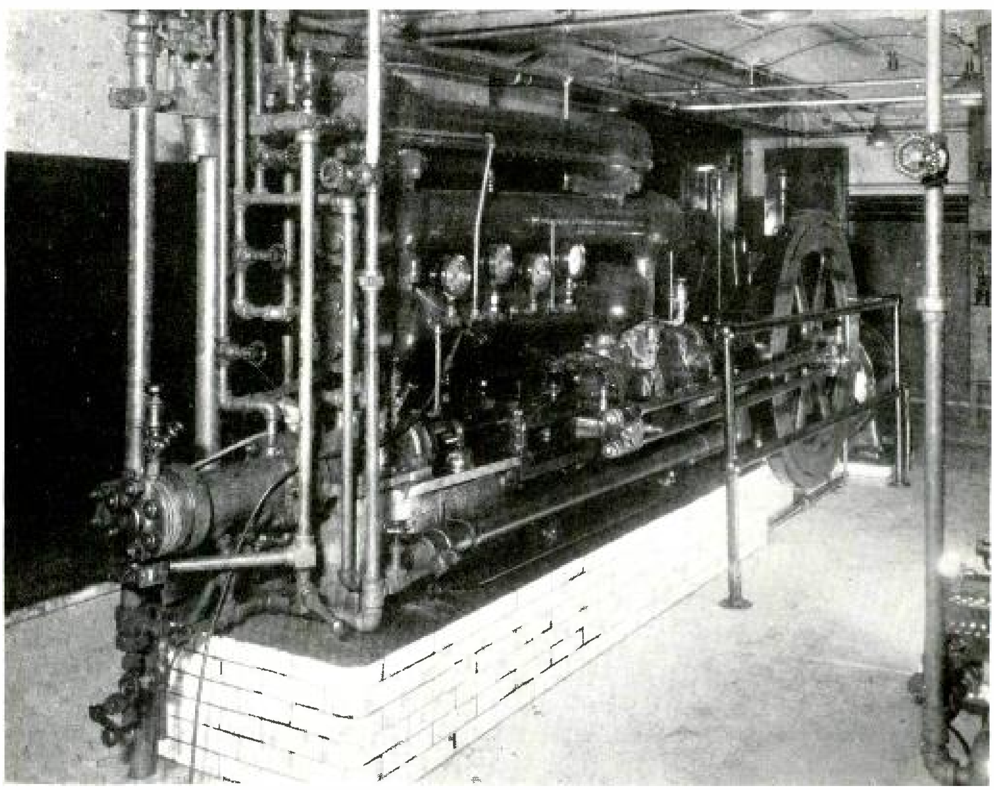


Fig. 1. This four-stage compressor brings air to a pressure of 3000 pounds per square inch

cooling-cylinder to the second compression-cylinder, where it is given a pressure of 175 pounds. In two more similar steps it is compressed to 910 and then 3,000 pounds, after which it is passed through two coolers in series—one being insufficient to carry away the extreme heat generated. Water from our own artesian wells is used for cooling; this water is always about seventeen degrees colder than that in the city water mains. The compressor is lubricated with a mixture of castile soap and water; oil would ignite under the high pressure, as does the oil in a Diesel engine.

Air at three thousand pounds pressure is piped to purifying tanks, shown in the background of Figure 2. A filter removes any foreign matter which may be suspended in the air. Caustic soda absorbs carbon dioxide, and calcium chloride removes all moisture. The two slender tanks in front of the purifiers are the final coolers, through which the air passes before going to the liquefiers, which are shown in the foreground.

An air liquefier is essentially an insulated tank inside of which is a coil of metal tubing. The air at a pressure of 3000 pounds passes down through the tubing, is released through a valve, and passes up around the tubing to escape from the tank by means of an opening at the top. As it leaves the tubing the air expands and cools; as it rises it draws some of the heat from the air coming down through the tubing. This self-cooling process continues for

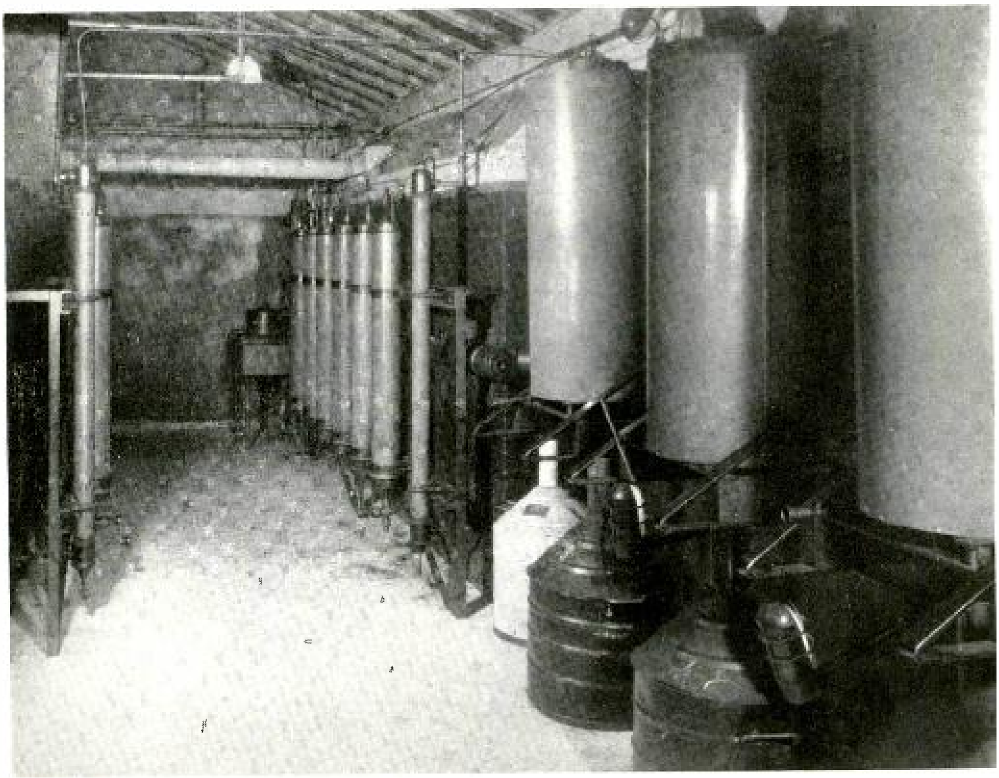


Fig. 2. From the compressor the air is piped to this room to be purified and liquefied. The liquefiers are in the foreground

about half an hour, when the air leaving the tubing finally reaches 312 degrees below zero, at which temperature part of it liquefies and collects in the bottom of the tank, while the rest rises in a gaseous form, continuing the cooling process. The liquid air collected in the tank is drawn off into copper vacuum-bottles; the larger part of it is sent to the Tube Shop on Hudson Street to be used in exhausting vacuum tubes, and the remainder is used in the laboratories for experimental purposes.

Bell System Researches

As recorded in articles recently published

Some studies in radio broadcasting transmission.—This paper[1] by Ralph Bown, De Loss K. Martin and Ralph K. Potter[2] is based on radio transmission tests from Station 2XB, the experimental broadcasting station in New York operated by the Bell Telephone Laboratories. It outlines the results of a detailed study of fading and distortion of radio signals under night-time conditions when received at two outlying field stations.

The idea that the strength of signals may differ considerably at a given time when slightly different frequencies are used, is confirmed. This difference in the fading characteristics of two frequencies is given the name of "selective fading." It was also found that when the same frequency is received by two stations separated by as small a distance as 1/16 wavelength the signal strengths are not the same and do not necessarily vary in proportion. These facts are interesting in that they show that the carrier- and side-frequencies radiated by a broadcasting station are not attenuated in the same way in passing through the transmitting medium. Distortion may therefore result.

When the carrier- and side-bands are separated by "heterodyning" the signal to a comparatively low frequency and passing the result through appropriate filters, the three amplitudes may be recorded with an oscillograph. Examination showed that maxima and minima for the different frequencies do not necessarily occur at the same time and hence that the signal is distorted between transmitter and receiver.

Fading observed at about 100 miles from the broadcasting station is assumed to be due to transmission along two major paths, the maximum signals usually being produced when the two components arrive in phase, the minimum when the components are out of phase. With the receiver at a fixed distance it was found under certain circumstances that two different frequencies faded oppositely, that is, one had a maximum value while the other had a minimum. It is shown that this can be explained by assuming two different paths differing by a definite distance. Assuming that one path is direct along the earth and the other depends on "reflection" from the "Heaviside layer" leads to a height of 110 kilometers for the reflecting layer. These experiments cor-

[1] *Bell System Technical Journal, Jan. 1926.*
[2] *All of the American Telephone and Telegraph Co.*

roborate the prevalent idea that the earth is the seat of a huge interference pattern.

One very interesting part of the paper deals with the distortion of a modulated wave when the frequency is not held constant during the different parts of the voice-frequency cycle. If there are two paths of unequal length along which waves may travel to the receiver, these two transmissions will be added in the receiver. If the frequency of the transmitter is constant, the two components will at all times have a constant phase-difference independent of modulation and there will be but little distortion. If, on the other hand the frequency does vary, the difference of phase will not be constant and serious distortion may result. It is shown that this distortion is eliminated when the frequency is stabilized. This is an important practical conclusion.—*Abstract by J. C. Schelleng.*

Some contemporary advances in physics.—The third of the articles[3] upon the Atom-Model is devoted to some of the many attempts which have been made within the last ten years to devise models for atoms of other substances than hydrogen and ionized helium. Owing to the extraordinary successfulness of Bohr's model for the atoms of these two substances, almost every designer of atoms has borrowed as many as possible for its properties to use in making his patterns for other elements. But the data are many and difficult to interpret, and not all of the properties of the hydrogen atom-model can be successfully transferred to the others; and on the other hand there are laws to which these other elements conform, which seem to demand pictures quite different from those which were sufficient for hydrogen. Consequently the scene is still one of confusion, and yet a confusion with unmistakable signs of progress and a great hope of achievement.—*Abstract by the Author.*

Correction of data for errors of measurement.—Three important types of problems arising in engineering practice are discussed in this paper.[4] These are: Error correction of data taken to show the quality of a particular lot or group of things. Error correction of data taken periodically to detect significant changes in the quality of product. Error correction of data taken to relate observed deviations in quality of product to some particular cause.

The solution of the first problem is presented for the first time. The solution of the second has been generalized to include cases not previously treated. The solution of the third is given in terms of previously developed theory.

Practically every kind of measurement must be subjected to some type of correction for error of measurement. Hence the theory given in this paper finds applications not only in engineering work, but also in physical, astronomical, psychological and other sciences. — *Abstract by the Author.*

Application of statistics in maintaining quality of manufactured product.—This paper[5] of W. A. Shewhart forms an introductory note emphasizing what appears to be a comparatively new field of application of statistical methods. Ways in which statistical methods may be used in helping to detect the existence of cyclic, erratic and secular fluctuations in product are outlined.

[3] *K. K. Darrow, Bell System Tech. Jour., Jan. 1926.*

[4] *W. A. Shewhart, Bell System Tech. Jour., Jan. 1926.*

[5] *Journal of the American Statistical Assoc., Dec. 1925.*

THEORY OF THE HOWLING TELEPHONE.—That a sustained oscillation is produced when the telephone receiver of a subscriber's set is brought close to the mouthpiece of the transmitter is common knowledge, but the complicated reactions underlying this phenomenon are probably not generally recognized. In treating this problem Harvey Fletcher in a paper[6] points out that in the production of such sustained oscillations, commonly known as "howling," four elements are involved; namely, the transmitter, receiver, mechanical coupling, and electrical coupling. Howling will be produced if the following conditions are fulfilled: Electrical power from a direct current source must be released in the form of electrical vibrations as the result of movements of the transmitter diaphragm. These electrical vibrations must be transmitted through the electrical coupling of the receiver, causing vibrations of its diaphragm.

These vibrations, in turn, must be transmitted through mechanical coupling to the transmitter, agitating its diaphragm and building up the process of howling to the point where the gain in the transmitter due to its amplifying action is just equal to the losses in the electrical and mechanical couplings.

The proper relationships must exist between the four elements to permit of the transfer of energy as outlined above. In determining the nature of these relationships, formulae are deduced which give the frequency and inensity of howling in terms of the constants of the system.—*Abstract by C. H. G. Gray.*

[6] *Bell System Technical Journal, Jan. 1926.*

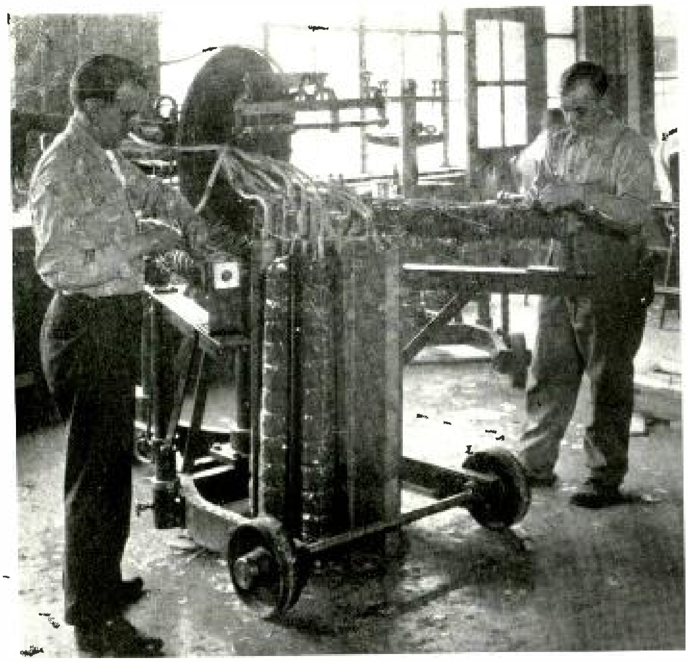
ASSEMBLY METHODS FOR LOADING COIL CASES

By ARTHUR H. FALK

IN metropolitan centers where the interoffice trunk lines are grouped in lead-covered cables, often miles in length, it is customary to improve transmission by the addition of inductance in the form of loading coils. Where the number and size of the interoffice trunk cables are large, and vault space for housing underground telephone plant equipment is at a premium, compact loading-coil cases for containing many coils are necessary.

The No. 43-A loading-coil case has been developed for this class of service. It pots 300 of the interoffice-trunk loading-coils and is among the largest loading-coil cases made, being over four feet high and approximately two and one-half feet in diameter. The shell is an iron casting.

Since the number of coils it contains is approximately three times the largest number of coils previously potted in one case, it has been necessary to develop a new method of assembly. In assembling by former methods the toroidal loading-coils are first arranged in groups on long wooden supports or spindles passing through the center of the coils. To the coils of each group are connected the conductors of a spindle cable. This is approximately a seventeen-foot length of machine-made cable and contains twice as many conductor



Preliminary Assembly Operations; Connecting the Stub Cables to the Coil Terminals

so that in drawing none of the cable conductors shall be broken.

A cable stub for a loading-coil case containing 300 coils made up in the manner described above would have a diameter considerably greater than the diameter of the standard 900-pair 22-gauge telephone cable which is the limiting size that can be handled satisfactorily. The stub would, moreover, have insufficient flexibility. It was, therefore, necessary either to adopt a design of loading-coil case using two cable stubs, or to splice a machine-made lead-sheathed cable-stub, which could be made sufficiently small, to short spindle-cables within the case or to adapt the previous practice to the new conditions. Economic reasons made it desirable to adopt the latter course.

pairs as there are coils. After the connections are completed each spindle assembly is securely wrapped with varnished muslin and placed in its proper compartment within the cast-iron case. When the last spindle is put into place the case is filled to the height of the top coil with a molten moisture-proofing compound, which is then allowed to solidify. This leaves about twelve feet of the spindle cables emerging from the top of the compound. These are then gathered together and formed into a single large cable. This cable is then wrapped with beeswaxed tape and drawn into a lead sheath to form the cable stub of the case.

The nature of the job makes it necessary to perform this last operation by man power. In the case of a large cable stub, the combined strength of eight or ten men is often required, although the sheath is made oversize

In the new method of assembly, as in the older method, the loading coils are first assembled on the long wooden spindles. The remainder of the assembly operations are completed with the aid of a large triangular truck which was developed by engineers of the Western Electric Company. The assembly of sheet-steel partitions for shielding the coils on one spindle from those on the adjacent spindles is placed on the floor within the triangular frame of the truck, as shown in the accompanying illustration. The cast-iron support which is to hold all the loaded spindles is hooked to a fixture of the truck directly above the partition assembly. At the rear is the cover of the loading-coil case.

Through a brass nipple in the cover passes a lead-sheathed cable stub made by machine to the proper size. This stub projects in the form of a coil from the outer side of the cover. On the other side its 1,200 separate leads are laid up in forms, each caring for terminals of the coils on a single spindle.

On the sides of the truck are adjustable hinged arms with notched uprights for holding the spindles on which the coils have been fastened. A man on each side of the truck fans the small stub units and splices the leads to the proper terminals of the coils on the spindle in front of him. As soon as all connections on a spindle are completed, it is wrapped and swung within the triangular frame of the truck into the place where the partition assembly is waiting to receive it. Two by two the groups of coils on the spindles are connected to their leads. When the last spindle is in place, the spindle support, together with a fixture for lifting it, is lowered into place over the tops of the spindles. It is then fastened by lugs to the partitions and to the spindle assemblies by large wooden nuts. The cover, spindle support, steel partition-assembly and spindle assemblies are now in the form of a single easily handled-unit.

A double overhead hoist, one part of which is fastened to the ring on the fixture supporting the spindle support and the other to the fixture supporting the cover and cable stub, is used to lift the entire unit out of the triangular truck and to lower it into the cast-iron case shown in the picture. When it is in place the spindle support is fastened to the case which is then filled to the proper height with moisture-proofing compound. The cover is swung into position and bolted down to the case over a red-leaded copper gasket and the case is then completely filled with compound through holes provided for that purpose

Final Assembly Operations; Lowering the Coil Assembly into the Case Casting

In common with all multi-spindle loading-coil cases an annular tongue on the cover enters an annular gutter on the flange of the case. Thus when the case is completely filled, the moisture-proofing compound flows into the gutter and around the tongue, forming with the gasket an extremely effective seal against the entrance of moisture and gases. A lead joint is then wiped between the cable stub and the brass nipple through which it enters the case. When the last check test has been made, the outer end of the cable-stub is sealed and the loading-case is ready for the field.

In the Month's News

At the Christmas holiday meeting of the American Association for the Advancement of Science in Kansas City there were addresses in the general sessions by two members of the Laboratories. Frank B. Jewett spoke of motive and obligation in research; a portion of his address is reprinted elsewhere in this issue. H. Clyde Snook spoke before an audience of about one thousand people describing recent advances in hearing and recording heart and lung sounds, which have already been described in previous numbers of the RECORD. His lecture was accompanied by a demonstration in which the audience listened to heart sounds through six large cone receivers. A No. 1 Public Address System was used to supply these cones with current from a portable electrical stethoscope. The installation of this system, which was a contribution to the success of Mr. Snook's talk and to the scientific meetings in general, was made by the Southwestern Bell Telephone Company through W. O. Pennell, Chief Engineer. The immediate arrangements were made by H. L. Pendleton of that company. Using this public address system, a phonograph turn-table, and an electromagnetic reproducer, Mr. Snook presented to his audience three records made by Dr. Cabot, as described in the RECORD for December. In addition he arranged a supplementary exhibit where each visiting scientist could hear and observe his own heart sounds. A No. 1-A electrical stethoscope was provided with a cathode ray oscillograph in a cabinet. What the observer saw then was a graph of his heart sounds.

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Edward B. Craft spoke to the Lehigh Valley Engineers' Club and the local section of the A.I.E.E. at Easton, Pennsylvania, on the evening of January 20th, on the subject "Research of Today, the Engineering of Tomorrow."

C. M. Bracelen, who since March, 1924, has been Vice-President and General Solicitor of the American Telephone and Telegraph Company, has been made Vice-President and General Counsel, succeeding N. T. Guernsey. The latter retains his duties as Vice-President but is relieved, at his own request, of his responsibilities as head of the company's Legal Department, in order that he may direct attention, among other matters, to the study of the broad legal principles of utility law and regulation.

In addition to his previous duties Mr. Bracelen is responsible for legal matters of the American Telephone and Telegraph Company, and for legal advice and assistance to the Associated Companies on taxes, patents and corporate financing.

On the road during December were various radio engineers. In St. Louis a 5000 watt station known as "The Voice of St. Louis" claimed the attention of H. S. Price, R. S. Bair and D. H. Newman. In Florida the Miami Beach Bay Shore Company's station, 1 kw., was installed under the supervision of J. C. Herber. Coke Flannagan travelled west to relieve J. S. Ward in the completion of the installations for the Bankers' Life Company in Des Moines and Sears Roebuck Company in Chicago. W. L. Tierney visited broadcasting stations using our equipment at Detroit, Providence, and Portland, Maine. In Texas, J. C. Crowley spent some time.

Several engineers of the Telephone Systems Department were engaged in field trials during January. In connection with carrier systems Ralph C. Hersh and Fred A. Brooks were at Cambridge, Ohio, and at other repeater stations, while Ralph E. Crane and Verl J. Hawks were at the St. Louis terminal and George H. Huber and Frank A. Muccio were at the Pittsburgh terminal of the Type "C" system which they were testing.

Robert L. Case spent about a week at Princeton in tests with American Telephone and Telegraph engineers on a special type of echo suppressor for telephone circuits. At Harrisburg, George N. Saul spent some days in testing improvements in the timing of echo suppressors for four-wire cable circuits.

Tola A. Marshall at Reading tested improved methods of locating breaks in cable circuits. Leslie F. Porter returned to Lansing, Michigan where he was again associated with members of the American Telephone and Telegraph Company in tests of the new toll boards (No. 3), this time in connection with the trial of new maintenance and test equipment.

Clayton A. Fischer, who is taking our Laboratory course of training for high-school graduates, gave a talk on his experience as a Student Assistant before the students and faculty of the Fort Lee High School from which he graduated. The occasion was the Alumni Day of the school, Thursday, January 7th.

Francis F. Lucas delivered a lecture to the Detroit section of the American Society for steel treating on high-power metallography. He also spoke to the Technology Club of Syracuse on the application of the microscope to industry.

Louis W. McKeehan attended the Christmas meetings of the Physical Society in Kansas City.

Bell Laboratories Club

Activities of an organization of 3300 people formed to promote the professional, social, and athletic interests of members of the Laboratories

Rifle Club

In February, 1925, the Club took part in the first transcontinental rifle match, with the Hawthorne team and a team of the Pacific Telephone and Telegraph Company in San Francisco. The California men won the match, with our team second. The success of this undertaking aroused an interest that spread throughout the entire Bell System, and when the second annual match is held in February, 1926, teams from ten different cities will take part. Some of the cities represented will be Los Angeles, San Francisco, Denver, Kansas City, Chicago and New York. A. H. Leigh, extension 245, is always ready to arrange for a new member a chance to qualify for the team.

C. Maurer, high individual point-scorer of the Basketball League

Swimming Meet for Men

The Club has received a number of requests for a swimming meet for men. It is its policy to promote any activity for which there is sufficient demand and a meet will be held some time in March, if enough applications are received by David D. Haggerty.

Christmas Poster Contest

The prize in the 1925 Christmas Poster Contest was awarded to Miss Peggy Anderson of the Equipment Drafting Division, whose design was judged the best of the twelve submitted. All the posters were good, showing considerable originality in conception and skill in execution. It is not easy to create a poster; the committee in charge is grateful to the members of the Laboratories who submitted designs, and hopes that an even larger number will enter

C. R. Barney, general secretary of the Bowling League the next contest. The winning poster was done in red and green with a background of snow and pines. In the foreground two cheerful figures, engaged in singing carols, formed the composition about the inscription: "Christmas Greetings from One to Another."


Our hikers stop for a rest

Chess Club

Our team in the commercial chess league of New York City still holds first place, as the following league standing shows:

	Matches		*Games*	
	Won	*Lost*	*Won*	*Lost*
Bell Laboratories Club........	4	0	14	2
Chase National Bank.........	3	1	12	4
Tide Water Oil Company.....	2½	½	9	3
Western Union Telegraph Co..	2	1	9	3
Brooklyn Edison Company....	2	1	7	5
New York Edison Company...	1½	1½	5½	6½
Guaranty Trust Company	1	2	5	7
McGraw-Hill Book Company..	0	3	½	10½
The New York World	0	3	0	12

The players who have taken part in this year's league matches are: F. A. Voos, H. M. Stoller, C. F. Sacia, H. T. Reeve, H. A. Whitehorn, H. D. Cahill, and D. A. Quarles.

Men's Basket-Ball

After a two weeks' holiday, the men's basket-ball league has settled down, and from now until the end of the season four games will be played each week.

All of the games will be well worth watching, as the teams are more evenly matched than the league standing would lead one to believe. This season has brought out a number of new players who have strengthened the teams. While Commercial and Equipment are leading, it is entirely too early to predict who is going to carry off the Spalding trophy. Before the season is completed each team will have played fourteen games.


The "Signals," leading Class C Bowlers. Standing: A. J. Spielberger, D. W. Pitkin. Seated: H. Waller, J. F. Jessich, J. S. Elliott

The members of the leading teams are:

Equipment — O. L. Michal, C. W. Christ,

The "Lamps," leaders in Class A. Standing: J. Stranahan, A. Zeiss. Seated: F. Lohmeyer, E. H. Chatterton, L. E. Parsons

W. P. Trottere, C. F. Gittenberger, L. W. Drenkard, J. J. Mallen, A. W. Frey, R. V. Rice, A. D. Turner; Commercial—W. Steinmetz, A. T. Hansen, R. C. Fisher, C. F. Bisenius, A. Wolff, C. Maurer, J. Smith, T. A. Ryer.

League Standing, January 11, 1926

Team	*Won*	*Lost*	*Percentage*
Commercial	3	0	1000
Equipment	3	0	1000
Tube Shop	2	1	666
Toll and Circuit	2	1	666
Research	1	2	333
Patent-Inspection	1	2	333
Apparatus Development	0	3	000
Junior Assistants	0	3	000

Bowling League News

Each year the interest in bowling among the men from West Street has grown until now the league is the most successful activity of the Club and the officials are faced with the problem of finding places for all those who wish to take part. One hundred and twenty men turn out every Friday evening for thirty weeks and in addition to them there are one hundred more who occasionally bowl as substitutes.

The present league originated in 1921, with twelve teams representing various departments at West Street. Since then it has grown until now twenty-four teams take part. The organization of all of the teams takes place each year and is based on the individual averages for the previous season. The twenty-four teams are grouped into three classes with equal prizes for each class. This plan gives to the

E. P. Bancroft, a leader in Class A

men in each group a chance to win prizes without competing outside their own class.

O. L. Mabey, the first president of the Bowling League, served two years. He has been succeeded by J. G. Dusheck, L. E. Parsons, and H. L. Bostater. The Club team in the Metal District League has won the championship for the past four years, and each year in the Metropolitan Open Championship we have carried off a fair share of the prize money.

The "Lamps," Class B leaders. Standing: I. R. Goshaw, Roberts. Seated: H. S. Enger, W. E. Bisp, C. E. Flaig

In this issue we are publishing pictures of two of our class "A" bowlers whose consistently high averages give us assurance that they will always successfully represent West Street in its outside competitions.

C. D. Dusheck, another leader in Class A

League Standing, January 11, 1926

	Won	*Lost*	*Average*	*H. Sc.*
Group A				
Lamps	26	16	841.3	937
Plugs	25	17	828.9	968
Buzzers	24	18	830.9	954
Coils	24	18	824.6	960
Cables	20	22	840.4	982
Relays	19	23	824.9	926
Ringers	15	27	815.8	963
Signals	15	27	815.4	916
Group B				
Lamps	31	11	730.5	819
Relays	27	15	708.2	833
Buzzers	23	19	709.6	790
Ringers	22	20	700.1	797
Coils	18	24	697.3	811
Signals	17	25	699.0	814
Cables	15	24	699.1	785
Plugs	15	27	713.0	859
Group C				
Signals	30	12	689.0	815
Coils	28	14	686.8	809
Plugs	25	17	668.1	761
Relays	21	21	659.0	771
Buzzers	20	22	671.3	806
Lamps	18	24	654.8	810
Ringers	13	29	660.6	777
Cables	13	29	649.9	803

Board of Advisers

IN the January RECORD the names of the president, first vice-president, and second vice-president of the club chosen at the recent elections for the year 1926 were announced. Three new members of the Board of Advisers were elected at the same time, to serve through 1926 and 1927. Lester B. Eames, of the Apparatus Development Service group, will represent the Apparatus Development Department; James G. Motley, Assistant Plant Manager, was chosen from the Plant Department; and George Heydt, of the Patent Department, will look after the interests of Patent, Inspection, and Staff.

The three other members of the Board, chosen at the preceding election to serve during 1925 and 1926 are: Kenneth B. Doherty, General Service Manager; John J. Fennelly, Research Service Department; and John V. Moran, Systems Development Department. Club policies are kept more uniform by thus interlocking terms.

Each year the six elected to the Board of Advisers appoint five additional members to have charge of certain specific activities. The appointees this year are: J. O'Connell, Tube Shop Club; Edward J. Johnson, Athletics; Herbert L. Bostater, Bowling; Hugh M. Stoller, Cards and Chess; and Helen Cruger, Women's Interests.

Chairmen of the various other Club activities, elected last year, were named in the November RECORD. There have been no changes since that time.

The basketball trophy, presented to the Laboratories by A. G. Spalding & Bros.

Spring Dance

The annual Spring Dance will be held this year in the Grand Ballroom of the Hotel Pennsylvania on Tuesday evening, April thirteenth. Ben Bernie of the Hotel Roosevelt, whose "I hope you'll like it!" is well known to all of WEAF's listeners-in, will provide the music. There are few who could do it better.

There will be special features of some sort; Chairman McCormack's plans for this part of the entertainment, however, have not yet been completed, so that it is impossible now to make a definite announcement.

Swimming Meet for Women

The women's swimming meet announced for January 20th in the last RECORD has been postponed. It will be held at the Carroll Club, in Madison Avenue, some time during March.

The Semi-centennial of the Telephone

On March Tenth, 1876—

THE telephone transmits its first sentence. Alexander Graham Bell speaks to his assistant Thomas Alva Watson who is in the next room. ¶ "Mr. Watson, come here, I want you," he says into the transmitter; and Watson hears the complete sentence from the telephone receiver. ¶ Only a few feet of wire separate the two instruments. The sound is not loud; the reproduction is not perfect; but the crucial experiment has been performed. Bell's theories and the principles upon which his invention are based are verified by the transmission of these simple words. An operative device has been constructed in accordance with these principles. ¶ For the first time there is a telephone! Bell's dreams have come true! His genius and persistence have embodied his dream in the wonder instrument of the age, a device of service to mankind.

On March Tenth, 1926—

A HUMAN institution dedicating its advancements and applications of science to the development of electrical systems of communication and its efforts to their operation for the service of mankind. ¶ A telephone system owned in shares by thousands of citizens of our Country and operated loyally by thousands of servants to the public. A growing network of wires bound together at central offices and toll boards, covering each year more territory, carrying more messages, speeding the spoken word. ¶ Large laboratories and factories instead of a small house. Thousands of scientists and assistants instead of two men. Clear and natural telephonic transmission over commercial instruments instead of laboratory models. ¶ All the results of fifty years of painstaking study and experiment, of work done with the joy of creation and the devotion of service. ¶ A future which beckons to even greater achievement.

3rd mo. MARCH 1926

On March 10, 1876, the first complete sentence of speech was transmitted by wire. Since June 2, 1875, when Alexander Graham Bell had discovered the principle of telephony, he and his assistant, Thomas A. Watson, had worked tirelessly to "make the telephone talk." Over a wire stretched from one room to another Bell now called, "Mr. Watson, come here, I want you." Watson rushed into Bell's room to announce breathlessly that he had heard and understood the summons. Speech had been transmitted by wire. Thus began the development of an art which has made possible direct, personal intercommunication between the users of more than 16,600,000 telephones which the Bell System has linked together for nation-wide, universal service.

MOON'S PHASES

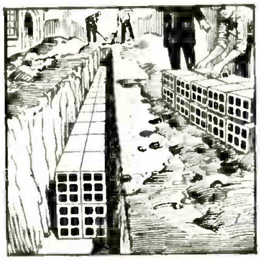
Eastern Time D. H. M.	For Central Time, deduct 1 hr.; Mountain Time, 2 hrs.; Pacific Time, 3 hrs.
7 6 50 A. M.	
13 10 20 P. M.	
21 12 12 A. M.	
29 5 0 A. M.	

♓

♈

MARCH *hath* 31 days — *"Give to a gracious message an host of tongues"*—Shakespeare

FAMILIAR SIGHTS



Underground Cable

Underground telephone cables are run through conduits divided into compartments to accommodate a number of cables. The cables are pulled into the conduits through manholes located at intervals along the cable line. These also afford access to the cables when repairs are required. Many underground cables have a capacity of 2,400 wires or more. The wire mileage of Bell System wire in underground cables on July 1, 1925 was 28,340,072 miles.

Say the Weather-wise:

The larger the halo about the moon, the nearer the rain clouds and the sooner the rain may be expected.

There was an average of about 67,700,000 telephone calls a day in the United States in 1925. This would amount to 2,820,000 calls every hour if the traffic were evenly distributed over day and night.

March

Ah, March, we know thou art kind-hearted, spite of ugly looks and threats,
And, out of sight, art nursing April's violets.
—*Helen Hunt Jackson.*

1 M.—First telegram from New York received in Detroit, 1848.
2 Tu.—Colonial Post Office established by New York, 1685; Territory of Nevada organized by Congress, 1861; Texas declared her Independence, 1836.
3 W.—***Alexander Graham Bell, Inventor of Telephone, born in Edinburgh, Scotland, 1847.*** Postage stamps first authorized in U. S., 1847; Congress appropriated $30,000 to build telegraph line between Baltimore and Washington, 1843.
4 Th.—***President Harding's inaugural address heard by 125,000 people, by means of Bell "Loud Speaker" apparatus, 1921.*** Chicago incorp. as a city, 1837.
5 Fr.—***Complete telephone circuit comprising wires and wireless between New Canaan, Conn., and S.S. "America," 400 miles at sea, demonstrated by Bell System engineers, 1922.***
6 Sa.—First exhibition of telephone in Michigan, 1877.
7 Su.—***First Telephone Patent taken out by Bell, 1876.***
8 M.—British Stamp Act passed by House of Lords, 1765.
9—Tu.—Monitor defeated Merrimac in first "Ironclad" naval battle, 1862.
10 W.—FIFTIETH ANNIVERSARY OF TELEPHONE. First complete sentence of speech transmitted over a wire by Alexander Graham Bell to Thomas A. Watson, Boston, 1876.
11—Th.—Great blizzard of 1888 began.
12—Fr.—General Post Office established by Congress, 1789.
13—Sa.—Trinity Church, New York, opened for services, 1698.
14—Su.—First town meeting held in Faneuil Hall, Boston, 1743; Cotton Gin patented by Eli Whitney, 1793.
15—M.—Paid fire department in Philadelphia went into operation, 1871.
16—Tu.—Samoset the first Indian to visit Pilgrims, 1621.
17—W.—*St. Patrick's Day.* British evacuate Boston, 1776.
18—Th.—First Pension Act passed by Congress, 1818.
19—Fr.—U. S. divided into nine military districts, 1813.
20—Sa.—Private companies own 71% of the world's telephones.
21—Su.—SPRING BEGINS. Bank of New York incorporated, 1791.
22 M.—Americans under Gen. Winfield Scott shelled Vera Cruz, Mexico, 1847; Interstate Commerce Commission appointed, 1887.
23—Tu.—Patrick Henry delivered his famous speech—*"Give me liberty or give me death!"* 1775.
24—W.—Rhode Island purchased from Indians, 1636.
25 Th.—First city directory in America, Philadelphia, 1785.
26 Fr.—First Embargo Act passed by Congress, 1794.
27 Sa.—***Boston-New York long distance telephone line opened, 1884. Use the Bell to Sell!***
28 Su.—Palm Sunday. American Army under Gen. Taylor reached Rio Grande opposite Matamoras, 1846.
29 M.—***American Telephone and Telegraph Company annual dividend rate increased from $8 to $9 per share per year, 1921.***
30 Tu.—*"Uncle Tom's Cabin"* first issued in book form, 1852.
31 W.—First U. S. Mail to Pacific Coast reached San Francisco, 1849; Daylight Saving inaugurated in U. S., 1918.