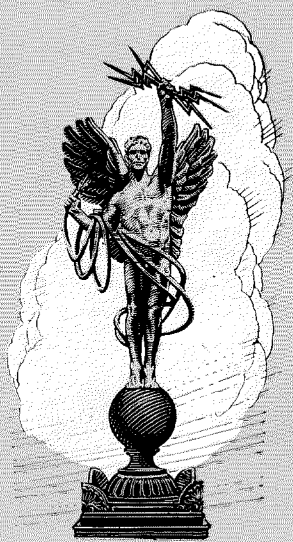
ELECTRICAL COMMUNICATION



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CONTENTS

HEADQUARTERS
American Telephone and Telegraph Company
and
Western Electric Company, Incorporated
195 Broadway, New York

Organization of the Bell Telephone System

THE management of an industry which is composed of widely separated parts requires not only a high order of talent but a systematic plan of organization, designed to coordinate the component elements into an effective unit.

The telephone business of a nation is of this character, and, inasmuch as the Bell Telephone System is the largest of its kind in the world, it is thought that the readers of ELECTRICAL COMMUNICATION would be interested in a description of its organization.

The Bell Telephone System is composed of twenty-five local operating companies (the Associated Operating Companies), a long lines company (the Long Lines Department of the American Telephone and Telegraph Company), a manufacturing company (the Western Electric Company, Inc.) and a central administrative department (the General Department of the American Telephone and Telegraph Company).

The local operating companies carry on the telephone business of the Bell System within their respective areas. The division of territory between these companies is shown in Figure 1.

The long lines company furnishes toll (i.e., long distance) service throughout the country, interconnecting the territories of the local operating companies. The toll circuits of the long lines company are shown in Figure 2 in heavy lines. The circuits of the local companies with which they connect are shown in light lines.

The manufacturing company supplies practically all of the apparatus and materials required for the plant of the local and long lines companies.

Each of these companies is complete within itself, but they are tied together by a system of centralized coordination through the medium of a central administrative department which makes it possible to provide practically universal telephone service of standard quality throughout the nation.

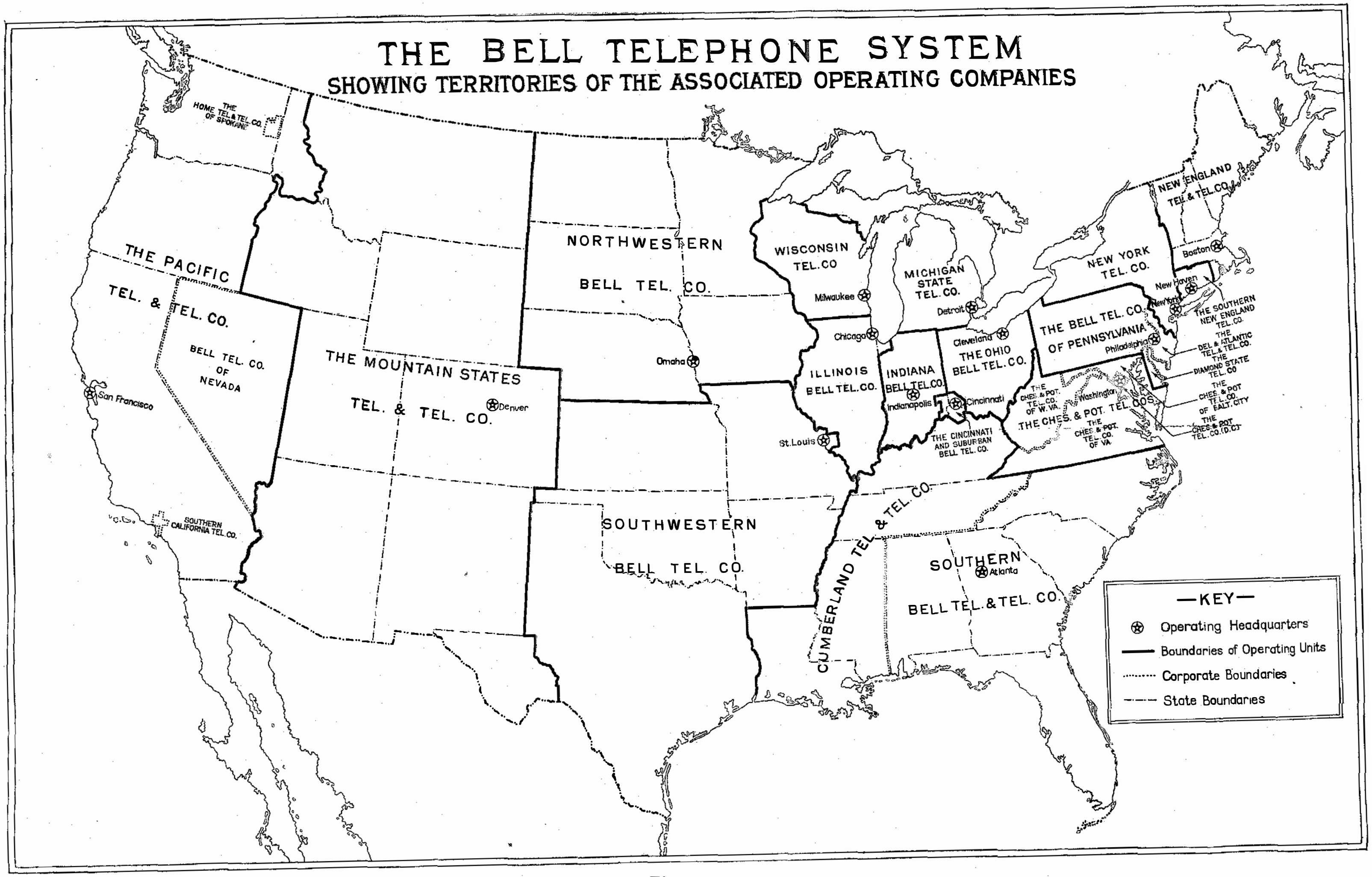
The central administrative department coordinates the activities of the local companies, the long lines company and the manufacturing company; it supplies and maintains the transmission instruments used by the operating companies, conducts scientific research and development studies for the benefit of the industry and recommends standard methods and practices for the operating components.

A representative plan of organization of a local operating unit, the New York Telephone Company, is shown in Figure 3. It will be observed that this organization provides for legal, financial and accounting departments, as well as for a general manager in charge of operations. The general manager's department is divided into four parts: commercial, engineering, plant and traffic.

The Commercial Department attends to such matters as contracts with subscribers for telephone service, collecting revenue from subscribers, preparing and delivering telephone directories, studies and recommendations for extension to meet prospective growth, studies of rate conditions and recommendations thereon.

The Engineering Department makes economic studies from which it prepares fundamental plans involving the location, character and extent of the more permanent parts of the plant, such as the subways, underground cables, central office buildings and trunking plant. It handles such matters as appraisals involved in the determination of rates, and assembles cost data bearing on plant construction and maintenance. It supervises the planning and erection of central office buildings and prepares the general and detailed specifications for the equipment to be placed therein for furnishing telephone service. It prepares and distributes to the plant and other departments information for applying to the plant the standards of construction, transmission, operation and maintenance which are developed by the central administrative department. In conjunction with the Commercial Department, the Engineering Department is charged with the responsibility for anticipating the needs of the communities served and it reviews broadly from time to time the situation with respect to the growth of the plant, and makes such further plans and recommendations as are necessary to keep pace with the requirements.

The Plant Department is responsible for the construction and maintenance of the plant or physical facilities. It prepares and executes the



THE BELL TELEPHONE SYSTEM
SHOWING TERRITORIES OF THE ASSOCIATED OPERATING COMPANIES
THE HOME TEL. & TEL. CO. OF SPOKANE
THE PACIFIC TEL. & TEL. CO.
San Francisco
BELL TEL. CO. OF NEVADA
SOUTHERN CALIFORNIA TEL. CO.
THE MOUNTAIN STATES TEL. & TEL. CO.
Denver
NORTHWESTERN BELL TEL. CO.
Omaha
SOUTHWESTERN BELL TEL. CO.
St. Louis
WISCONSIN TEL. CO
Milwaukee
MICHIGAN STATE TEL. CO.
Detroit
ILLINOIS BELL TEL. CO.
Chicago
INDIANA BELL TEL. CO.
Indianapolis
THE OHIO BELL TEL. CO.
Cleveland
Cincinnati
THE CINCINNATI AND SUBURBAN BELL TEL. CO.
THE BELL TEL. CO. OF PENNSYLVANIA
Philadelphia
NEW YORK TEL. CO.
New York
New Haven
Boston
NEW ENGLAND TEL. & TEL. CO.
THE SOUTHERN NEW ENGLAND TEL. CO.
THE DEL & ATLANTIC TEL. & TEL. CO.
THE DIAMOND STATE TEL. CO
THE CHES. & POT. TEL. CO. OF BALT. CITY
THE CHES. & POT. TEL. CO. (D.C.)
THE CHES. & POT. TEL. CO. OF W. VA.
THE CHES. & POT. TEL. CO. OF VA.
THE CHES. & POT. TEL. COS.
Washington
CUMBERLAND TEL. & TEL. CO.
SOUTHERN BELL TEL. & TEL. CO.
Atlanta
—KEY—
Operating Headquarters
Boundaries of Operating Units
Corporate Boundaries
State Boundaries

Figure 1

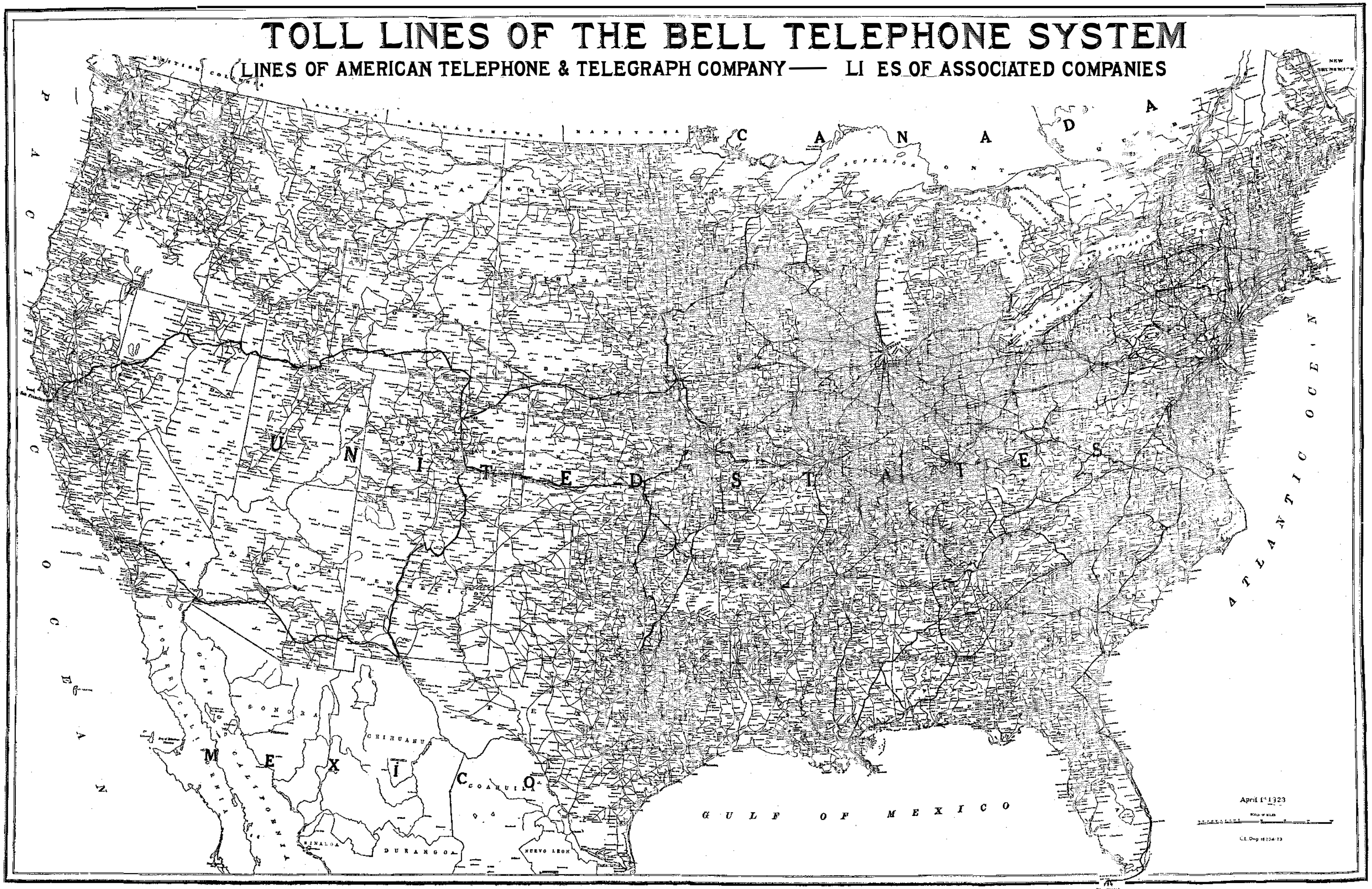

TOLL LINES OF THE BELL TELEPHONE SYSTEM
LINES OF AMERICAN TELEPHONE & TELEGRAPH COMPANY —— LI ES OF ASSOCIATED COMPANIES
C A N A D A
U N I T E D S T A T E S
M E X I C O
P A C I F I C O C E A N
A T L A N T I C O C E A N
G U L F O F M E X I C O
April 1st 1923

Figure 2

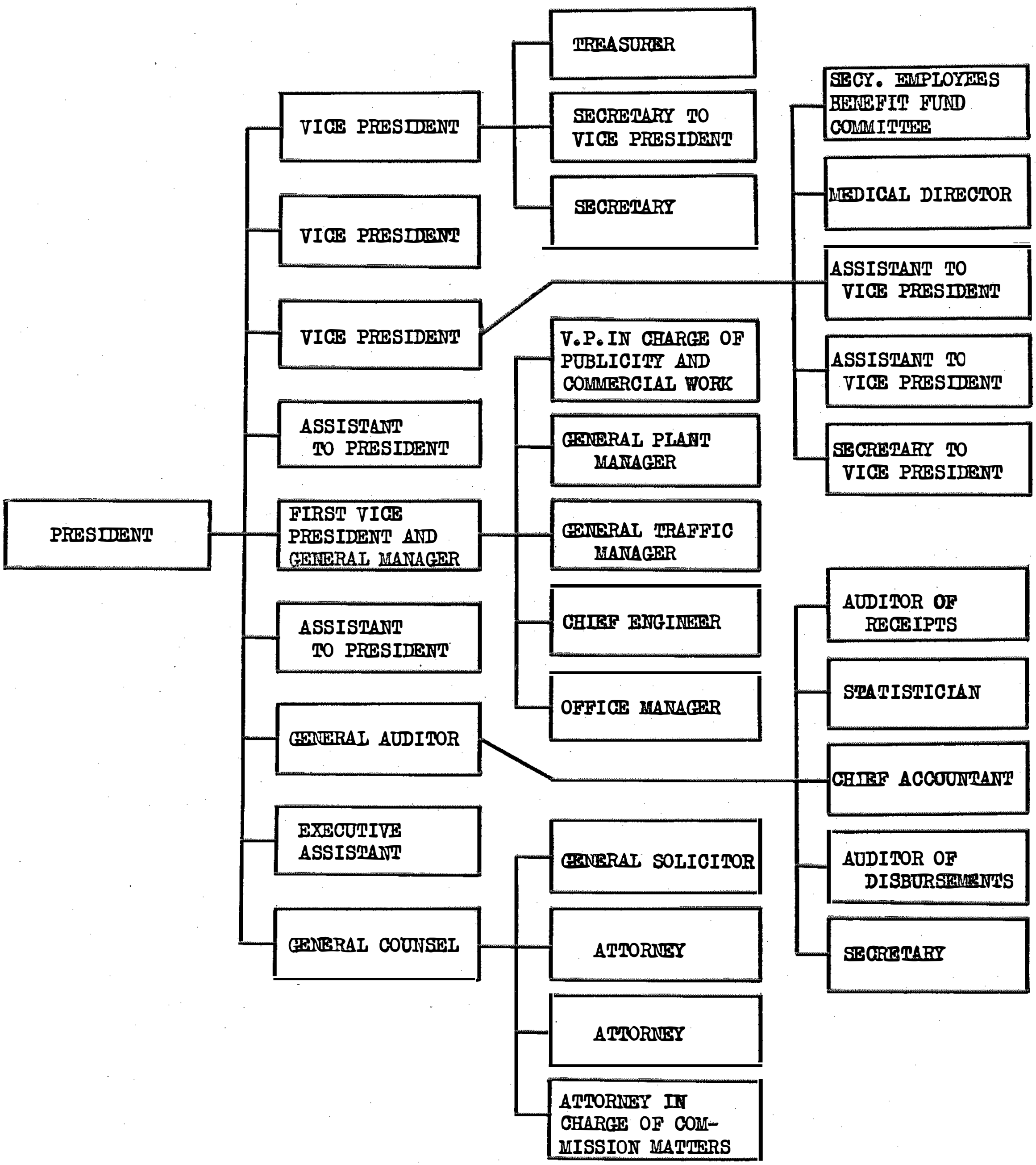


Figure 3—Organization Plan—New York Telephone Company

detail plans for subway and underground cable and for aerial cable and lines. It attends to the installation of the subscribers' station apparatus, such as telephones, private branch exchanges, building wiring, etc., and the installation of central office switchboards. It cares also for the maintenance of the plant, locating and repairing defects or troubles occurring in the lines, instruments and switchboards, and maintains the necessary record of the physical plant and its construction and maintenance costs.

The Traffic Department is responsible for telephone service as rendered the subscriber directly. It is its function to operate the central office switchboards, the information desks and such accessory equipment, also the toll switchboards of the local company. It observes the service and is accountable for its quality. It makes periodical records and checks of the character and volume of the calls handled, from an analysis of which is determined not only the number of operators required and their working schedule, but also the necessary increases and extensions in the switching equipment.

switchboards. Such buildings as it maintains are devoted to toll switchboards or toll and telegraph repeaters on toll lines. In the majority of cases the switchboards of the Long Lines Company are, for convenience, located in the buildings of the local telephone companies. However,

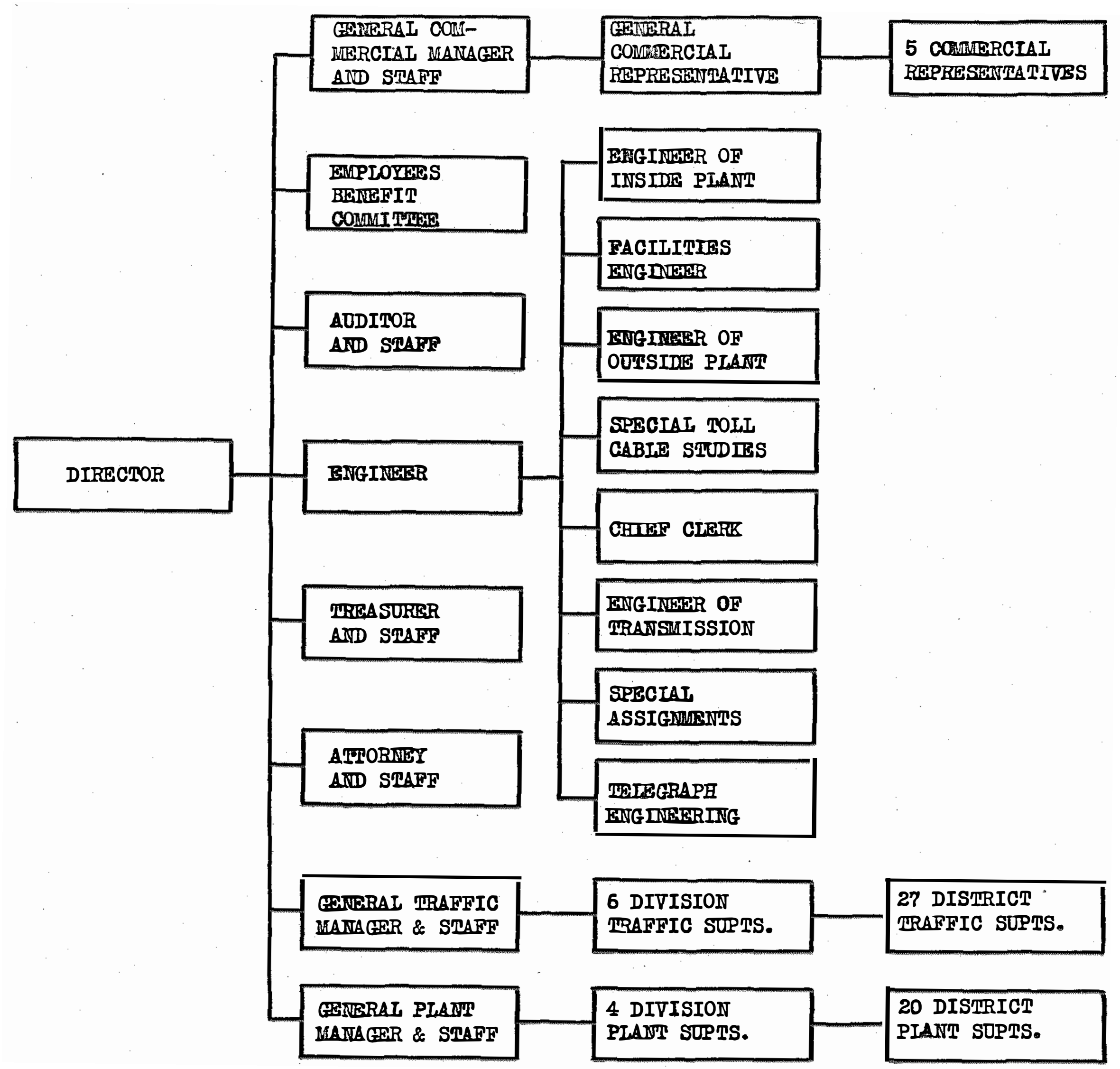


Figure 4—Organization Plan—Long Lines Department of the American Telephone and Telegraph Company

The Long Lines Company, the organization of which is shown in Figure 4, handles, in general, all toll line business not completed within the territory and over the toll lines of the local companies. It functions quite similarly to the local company except that its plant consists almost entirely of toll wires, cables and toll a separate and distinct group of operators and traffic supervisory force is maintained by the Long Lines Company for handling the interstate and long distance business. The functions of the various departments, such as commercial, plant, traffic and engineering, are identical with the corresponding ones of the local companies.

As will be seen by reference to Figure 5, the activities of the Manufacturing Company cover every phase of the problem of providing apparatus and material for carrying on comprehensive telephone service. Through its right to manufacture under the thousands of Bell patents involving all that is best and most efficient in the art of communication, it secures to the local and long distance telephone companies the lowest cost consistent with performance and the assurance of high standards and interchangeability.

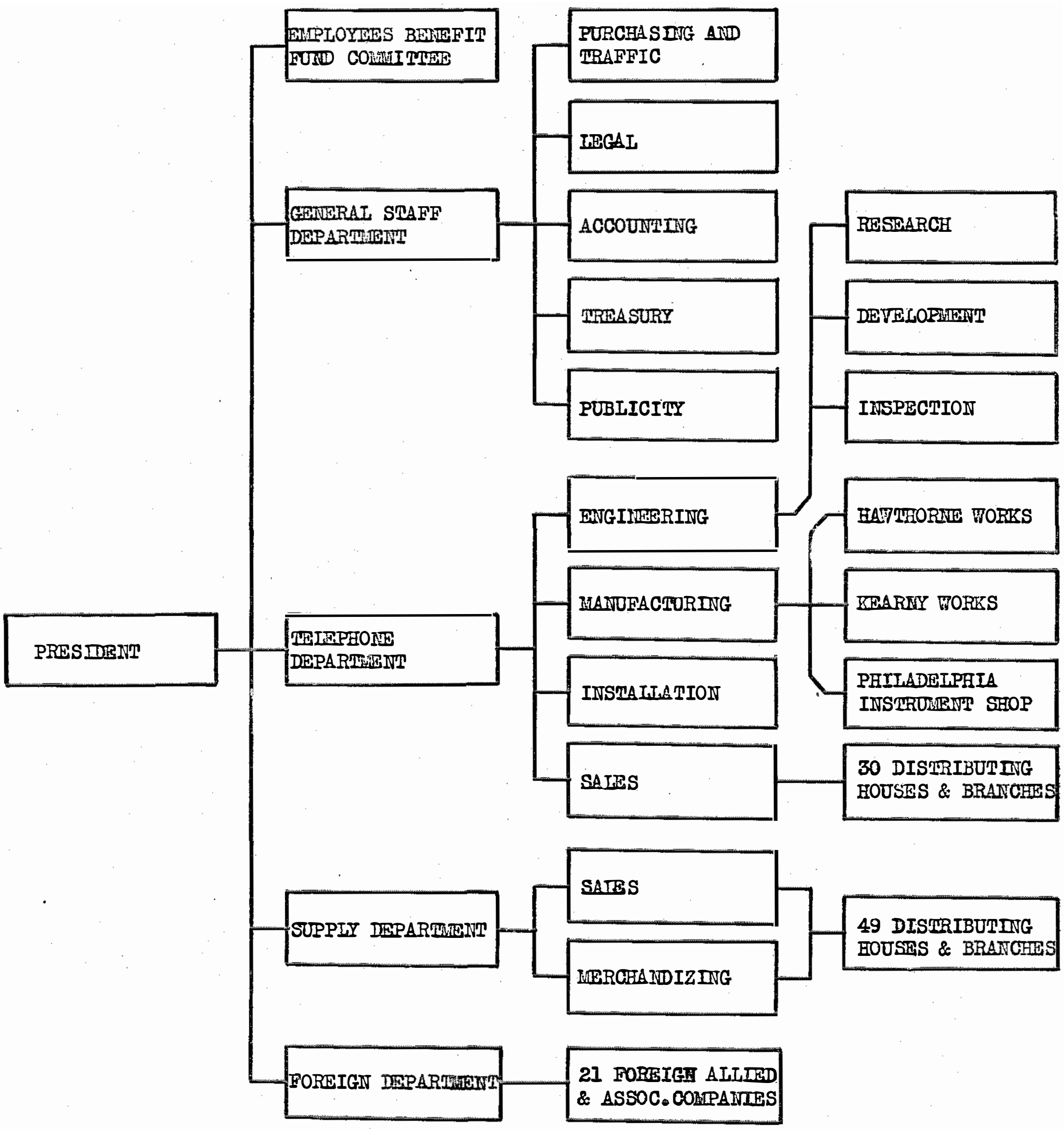


Figure 5—Organization Plan—Western Electric Company

In addition to its manufacture of the complete line of technical apparatus and equipment peculiar to telephone needs, the Western Electric Company acts also as the purchasing and distributing agent for all the various supplies and material needed in the business of the Bell System, such as poles, wires, cross-arms and construction hardware.

Through its Engineering Department the Manufacturing Company maintains a complete laboratory where a large corps of engineers is

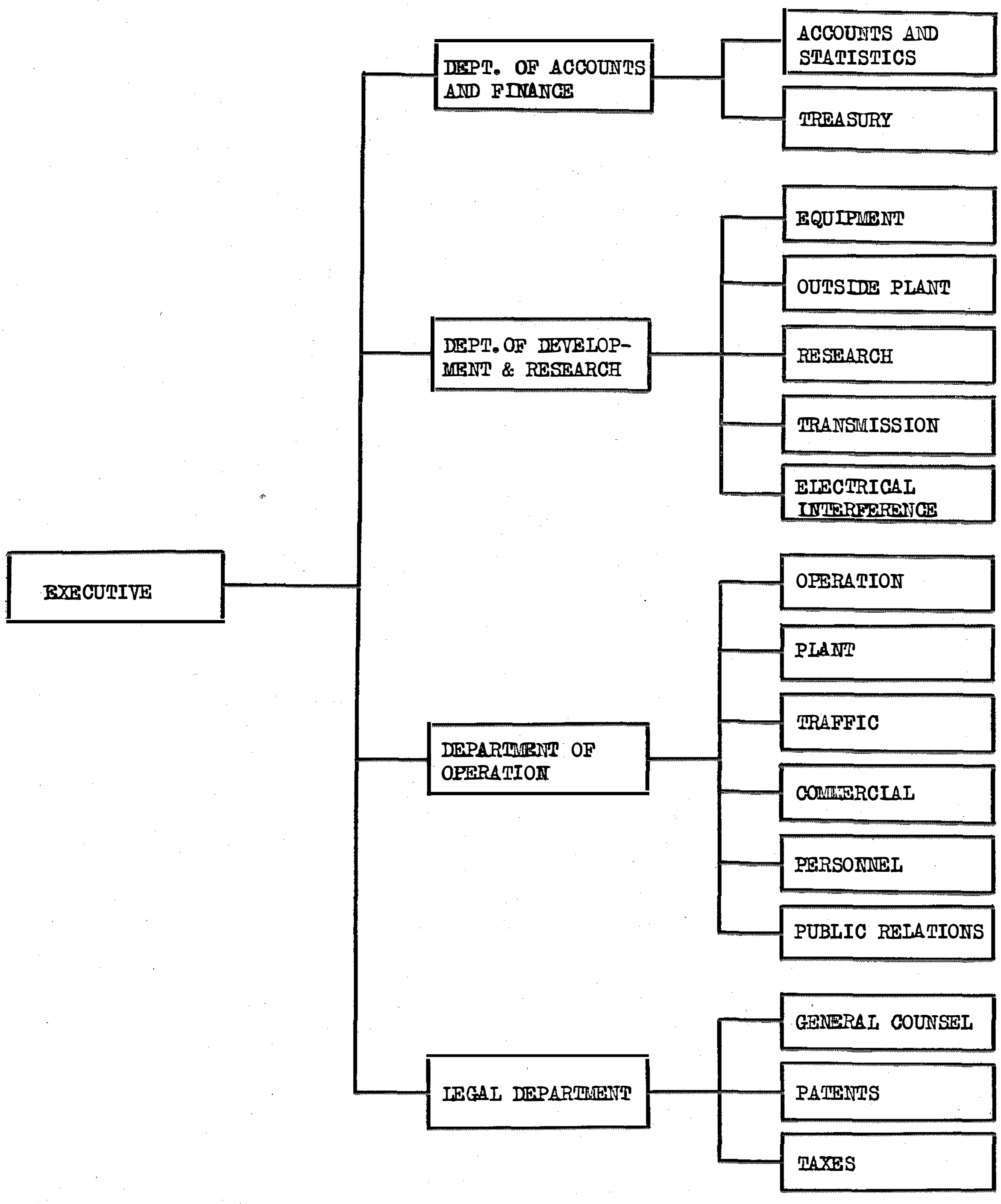


Figure 6—Organization Plan—General Department of the American Telephone and Telegraph Company

constantly engaged in the development of new ideas in conjunction with the development and research engineers of the central administrative department, looking to the constant improvement and extension of the means of communication.

The organization of the central administrative department—in other words, the General Department of the American Telephone and Telegraph Company—is shown in Figure 6. The subdivisions of this Department which serve purely corporate purposes are omitted from the diagram, which is confined to those activities which are involved in the execution of the primary function of the Department as the "General Staff" of the Bell System. Through the relationship of the American Telephone and Telegraph Company with its 25 associated local operating companies, the long lines company, and the manufacturing company, this General Staff is able effectively and economically to coordinate the activities of the whole Bell System and through its staff officers and their departments to give advice and assistance to all the component companies of the System.

The Department of Accounts and Finance studies the financial needs of the System and is responsible for the preparation and execution of a financial program whereby, through the sale of stock, bonds or other securities, the System is at all times provided with the many millions of dollars of additional capital necessary each year to meet the requirements of a constantly growing business. This department also develops the accounting and statistical methods used throughout the System and advises on all matters of accounting and statistical principles and procedure.

The Department of Development and Research is responsible for the development of new and improved apparatus and materials useful in the art of electrical communication and, in conjunction with the engineers of the manufacturing company, conducts the extensive experimental work incidental to this function. As a result of its researches, this department of the General Staff recommends standard types of apparatus and materials for use in the construction and the maintenance of Bell System plant.

The Department of Operation and Engineering studies the methods involved in commercial, traffic and plant work, and is responsible for the standardization throughout the System of those practices in the construction and operation of the System's plant and equipment which are most efficient from all aspects; and it advises as to schedules of telephone rates which will produce adequate revenues at the least burden to the public. As new developments are standardized by the Department of Development and Research, the Department of Operation and Engineering advises the associated operating companies in regard to their proper use.

Included in the Department of Operation, but headed by separate executives, are lodged the responsibilities for such functions as the maintenance of cordial relations between the management and the other employees, and the maintenance of mutually satisfactory relations between the System and other telephone companies, and between the System and the general public.

The Legal Department renders advice and assistance to the associated companies on all legal matters.

Trans-Oceanic Wireless Telephony

By H. W. NICHOLS, Ph.D.

Engineering Department, Western Electric Company

(This paper was presented at a meeting of the British Institution of Electrical Engineers in London on February 22, 1923.—EDITOR.)

THE American Telephone and Telegraph Company and the Radio Corporation of America have, for the last two or three months, been carrying on investigations to determine signal strength and other important data which will allow us ultimately to engineer a Trans-Atlantic radio telephone circuit, if this be desired. The following is a brief account of the important factors in such an engineering problem and of the course adopted to obtain the information necessary for its solution. I hope you will forgive me if a good deal of what I say to-night is somewhat elementary; I want to be sure you know exactly what is meant by some of the terms and phrases which have grown up in the last seven or eight years in connection with this art.

In order to introduce the subject as easily as possible, I would like to ask you to consider, first of all, a very simple type of telephone circuit, namely: a circuit consisting of a line, a microphone, a battery and a receiver, all in

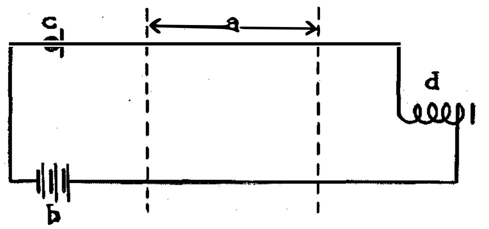


Figure 1

series. This is shown in Figure 1, in which (a) represents a telephone line, which, of course, is not the simple thing it is represented to be by the two wires. It has attenuation, and, ordinarily, the current at the sending end is greater than the current at the receiving end. (b) is a battery which sends a direct current through this circuit. I am going to refer to this continuous current as the "carrier" current. It is constant. (c) is a microphone, the function of which is to vary the amplitude of the otherwise steady current. It does what we call "modulate" the carrier current. (d) shows the simplest type of telephone receiver consisting of an electromagnet with a diaphragm on which the magnet can operate. All this, of course, sounds very simple, but it is important that we run over it. When the microphone is operating, the otherwise constant amplitude of the carrier current is varied slightly. The result is that there flows through the telephone receiver a current which is made up of two components, the first being a constant carrier current or something almost exactly equal to it, and the second is the signal, the variable ripple superposed on the carrier.

The telephone receiver itself, being an electromagnet, gives a deflection which is proportional to the square of the current flowing through it. This is indicated by the following formula:

$$(I_c+I_s)^2=I_c^2+2\,I_c\,I_s+I_s^2$$

If I_c represents the constant carrier current, and I_s the signal, the force on the diaphragm of the telephone receiver is proportional to the square of I_c plus I_s which, of course, is made up of three terms—I_c^2 (which is constant, because I_c is constant), the middle term $2I_cI_s$ (this is directly proportional to the signal, which is what we want to get) and I_s^2, which is proportional to the square of the signal, and consequently of double frequency, because any periodic function squared gives you a constant and a double frequency component. Consequently we do not want the third term.

If speech is to be of good quality in the receiver, the I_s^2 term must be small compared with the $2I_sI_c$ term; in other words, the carrier must be rather large compared with the signal, and this condition does obtain in the case of a simple telephone circuit of this kind.

This kind of circuit possesses two or three disadvantages which apply also to the radio circuit, and that is my only excuse for asking you to listen to it. In the first place, you will notice that the circuit requires that the battery should send current through the line. Now the battery current, that is the carrier current, contains no element whatever of signal, and consequently there is no need to transmit the direct current carrier from the transmitting end to the receiving end, except as a means for producing this middle term $2I_cI_s$ at the receiver. The transmission of the carrier current through the line, therefore, involves an unnecessary loss of power. This is one disadvantage.

Another disadvantage is this. This line, being an actual telephone line, will have both its attenuation and impedance varying with weather and other conditions. Now, if the characteristics of the line vary, then, since the carrier is transmitted from the transmitting end, both the I_c and the I_s in the middle term of that last expression will vary, and consequently we shall get the variation factor in the received signal squared, instead of to the first power.

The first obvious improvement on this simple system is shown in Figure 2. This differs from

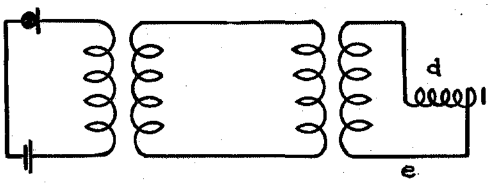


Figure 2

Figure 1, in that two transformers have been introduced. The first transformer restricts the carrier current to the transmitting apparatus, because that is the only place where it is needed. The variations in this carrier current go through the transformer and to the receiving end. At the receiving end, if we receive in the manner shown by this figure, we will get only double frequency signals, that is, we will not get intelligible signals, because the only thing that appears at the receiver is the I_s term. In order to make the signals intelligible at the receiving end, it is necessary to reintroduce the carrier current I_c, which, of course, in practical telephone apparatus, is done either by putting a battery at (e) or putting a permanent magnet in the telephone receiver. This change restores the conditions which existed at the receiving end under the conditions indicated by Figure 1.

In Figure 3 I have plotted as a spectrum the distribution of currents which must be passed by the line. It is well known that, in order to transmit intelligible speech, a range of frequencies of something like 3,000 periods is required.

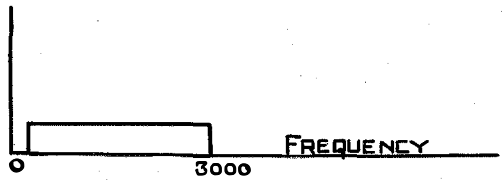


Figure 3

The microphone generates, and the line must transmit, a spectrum represented roughly by the rectangle in the lower part of the figure.

So far I have endeavored to bring out, firstly, the meaning of "carrier," and, secondly, the fact that the carrier does not contain any element of signal and need not be transmitted to the receiving stations. There are, in fact, real advantages gained by not transmitting it.

In Figure 4 I have shown exactly the same kind of circuit, except that the carrier current is now an alternating current of frequency f_c, delivered by the alternator. In other respects the transmitting end of the circuit is exactly the same. The microphone modulates the alternating carrier current, and the result of that modulation—the result of varying that alternating current's amplitude in accordance with speech—is to produce a spectrum represented by S_1, f_c and S_2, as in Figure 5. There is a carrier frequency component (f_c), and then there is a band, called the upper side band, extending up to the carrier frequency plus 3,000 periods; also there is another band, called the lower side band, extending down to the carrier frequency minus 3,000 periods; in other words, the effect of modulating an alternating current carrier by speech is to produce a spectrum twice as wide as the band which it is necessary to transmit.

At the receiving end, a device is shown which functions in a similar manner to the telephone receiver; that is to say, currents in the output circuit of the tube are proportional to the square of the voltage applied across its input terminals. This means that the tube conditions are so arranged that, if we apply a sine wave to the grid circuit, we will get a current of double frequency in the output circuit.

Exactly the same remarks apply to this circuit as to the simple telephone circuit. There is transmitted over the line a current having a spectrum as shown in Figure 5. The carrier component has no element of signal in it, and there is no need to transmit it over the line. If we do, then the effects of variations in the line will be squared in the receiving circuit, and, furthermore, we will use much more power if we transmit the carrier than if we do not. There are two very important advantages, therefore, to be derived from excluding the carrier from the line itself.

In order to exclude the carrier current, the device shown in Figure 6 is used.

Instead of getting the original spectrum, as in Figure 5, we shall get a new one, which contains only one-third of the power of the original one but still contains all the elements of the signal. The two side bands are exactly alike; we do not even need to transmit both of them. If we transmit only one of them, we shall still have all the elements of signal which were present in the speaking voice, so that by means of electrical filters we can cut out all but, let us say, the upper side band. In the receiving end, in exactly the same way as before, if we apply the side band directly to the receiving tube we

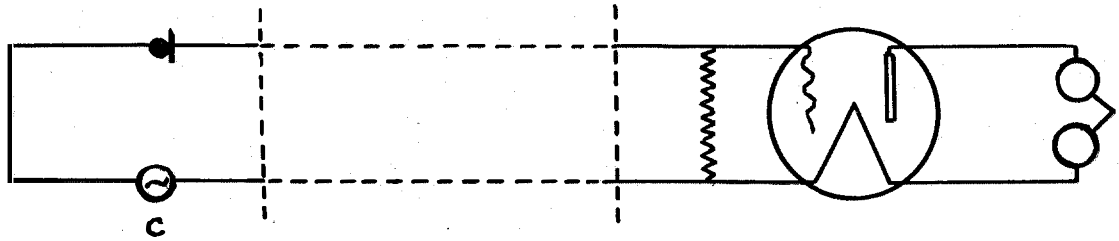


Figure 4

There are, of course, other ways of effecting the same result. The carrier current is generated by means of the alternator shown in the middle of the figure, and the speech which is to modulate

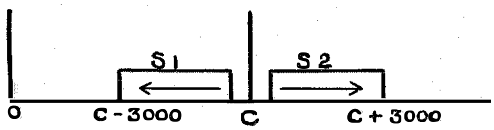


Figure 5

this carrier is applied at the left. If this circuit is examined, it will be seen, that if no speech is being applied, and if the tubes and transformers are quite symmetrical, the carrier current will produce no effect whatever in the output circuit of that system, because currents will flow down in the upper part of the transformer winding and equal currents will flow up in the lower part of the winding. As soon as we begin to speak, however, the tubes will be unbalanced, and we shall secure an output which is proportional to that unbalance, and the peculiarity about the output is that there will be no carrier frequency component present. That is shown by the spectrum, indicated in Figure 7.

will get in the output circuit of that tube a signal which is unintelligible, because it is proportional to the square of the input. Consequently it will be of double frequency. However, if at the receiving station we introduce again the carrier component in exactly the same way as we did in the case of the simple telephone circuit, and then square the result—that is, detect the signal—you can see very easily by the binomial theorem, that we will get exactly the same condition as before—one component which is directly proportional to the signal, and that is what we want to get.

Time will not allow me to discuss exactly what happens in detection. In general there will be developed in the output circuit frequencies which contain all the possible combinations that can be secured by addition and subtraction from all the impressed frequencies.

Just one word more on this. The effect of transmitting only one of these side bands, if it were due to a simple sine wave, would be that we would use only one-sixth the amount of power in the complete modulated wave.

So far I have been talking about wires. The only difference between wire transmission and radio transmission is in the medium used for it.

Radio transmission must, of course, take place through what is known as the ether. The ether differs considerably from a conductor; it is very much more like a condenser than a copper wire. Consequently, in order to get signals through it, it is necessary to use rather high frequencies, because low frequencies cannot be transmitted. Another difference between the ether and a copper wire is that the ether forms, as it were, a common circuit connecting every one. Unless directional methods of transmission and reception are used, the only way in which we can discriminate between channels in the ether is on the basis of frequency. There is another, and a very important, difference between the ether and a copper wire, and that is that its transmission characteristics are very much more variable than is the case with a wire circuit. There is a tremendous difference, for example, between day and night transmission; there is a large difference at different times of the day, and, what is still more annoying, there is a variation which goes on from minute to minute, or from second to second almost, especially with short wave lengths, which it is very difficult to take care of.

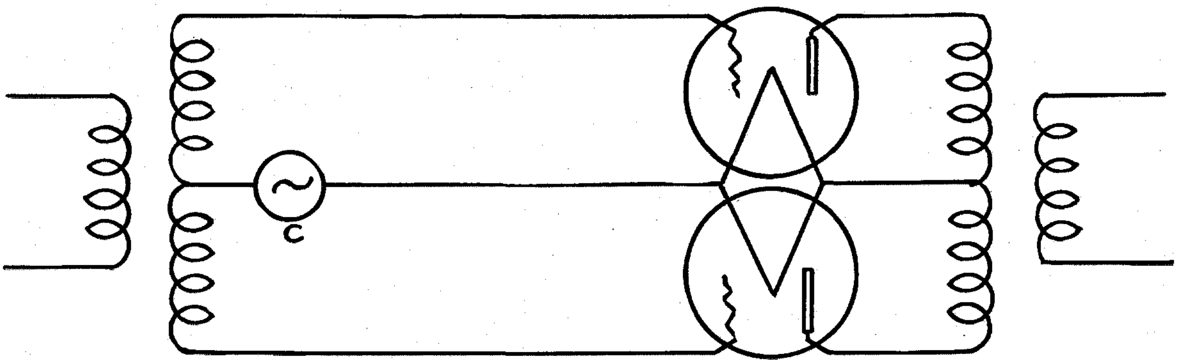


Figure 6

With that introduction, I should like to mention what factors are important in the design of a long distance radio telephone circuit—as I see them, of course.

In the first place, it is necessary to use rather long waves. The reason for this I shall bring out when I come to discuss the measurements which we have made. In the second place, it is obviously necessary to secure as great an economy in power as possible, because the power involved in trans-oceanic telephony is likely, in the summer time, to reach up to 1,000 kw. In the third place, it is extremely important not to use any wider frequency range than is necessary. I have already mentioned that a frequency band about 3,000 periods is required to transmit the human voice with good quality, and even more is needed to transmit music with good quality. We cannot transmit more than one channel in a given frequency range in the same direction.

The range of wave-lengths available for trans-atlantic communication is at present fixed by the London Convention, and probably will not be changed very much in the near future. The range of wave lengths available is from 8,000 metres up. Now, 8,000 metres is equivalent to 37,500 periods, and about the greatest wave length that we are likely to use in the immediate future will be about 30,000 metres, equivalent to 10,000 cycles. That is to say, there is available for trans-atlantic communication a frequency range of 27,500 periods. We can use that and we want to use it in the most efficient manner possible. Suppose we wish to use it for telephony. If we modulate in the usual way, we will produce a carrier and two side bands, each of the side bands 3,000 periods wide, making a total of 6,000 periods which must be trans-

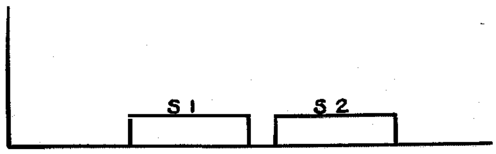


Figure 7

mitted. Using that 6,000 periods, in the 27,000 odd periods available, we can only have four telephone channels. What is worse, if we do that we cannot allow any telegraphic communication at all, because that frequency range will already be used, and there are 20 or 30 telegraph channels which must be taken care of. You will see, therefore, that it is extremely important to use as few periods as possible in this transmission.

For that reason, I think that for trans-atlantic communication by radio telephony, it is essential to transmit only one of the side bands. In that way we multiply the possible number of channels approximately by two; or, in other words, we leave free for telegraphic traffic a very considerable range of frequencies, because we can operate approximately 10 telegraphic channels in the frequency range required for one telephonic channel. We must not waste the frequency range available in the ether for telephony by transmitting the complete modulated wave.

We have built up radio telephone apparatus which conforms to our ideas of what such apparatus ought to be; it economises in power by sending out only one side band, and it occupies the minimum frequency range by the same device. It is fortunate that those two conditions can be achieved by the same means. I am going to describe very briefly what this apparatus is, and then show some illustrations of it.

We commence by developing a modulated wave at very low power of the order of one watt or less—employing vacuum tubes of the type used in telephonic repeaters. That is, we generate both side bands but not the carrier; the carrier is eliminated by the balanced modulator system which is shown in Figure 6. Then by means of filters, we cut out one of the side bands, because both are not necessary, and the result is that we have a fraction of one watt of single side band high frequency telephone current of about 55,000 to 57,000 periods. The next thing we do is to amplify this to about 300 watts by means of an amplifier consisting of three stages. From there it goes to another amplifier by means of which it is raised to a power level of about 5 kw. From there it goes to still another and larger amplifier which is capable of raising the power to 200 kw. but which, in the tests

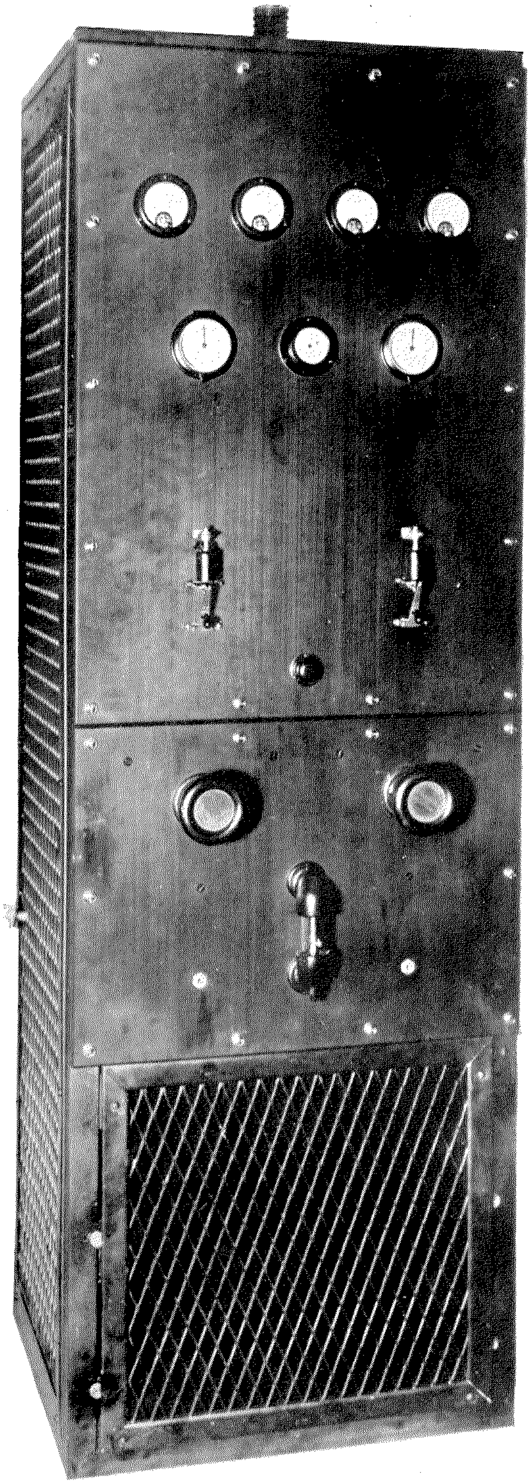


Figure 8

which we are running now, actually raises it only to 60 kw. because that is all we need. From the final amplifier it is passed to an antenna, which in this case is one of the Radio Corporation's antennae at Rocky Point.

There is one further argument in favour of this single side band transmission, which is this: if we are transmitting at 60,000 cycles we cannot design an antenna which will have a perfectly flat frequency characteristi 6,000 periods wide at 60,000 cycles; that is, 10 per cent of the frequency. By sending only one side band it is necessary to have the response fairly uniform over a frequency range of only 6 per cent of the frequency. Before I give you any illustrations of the apparatus, there is one important thing to emphasize. This 60 kw. which we have been using in our tests is just the same in its effect as approximately 250 kw. or more of complete modulated wave as ordinarily produced.

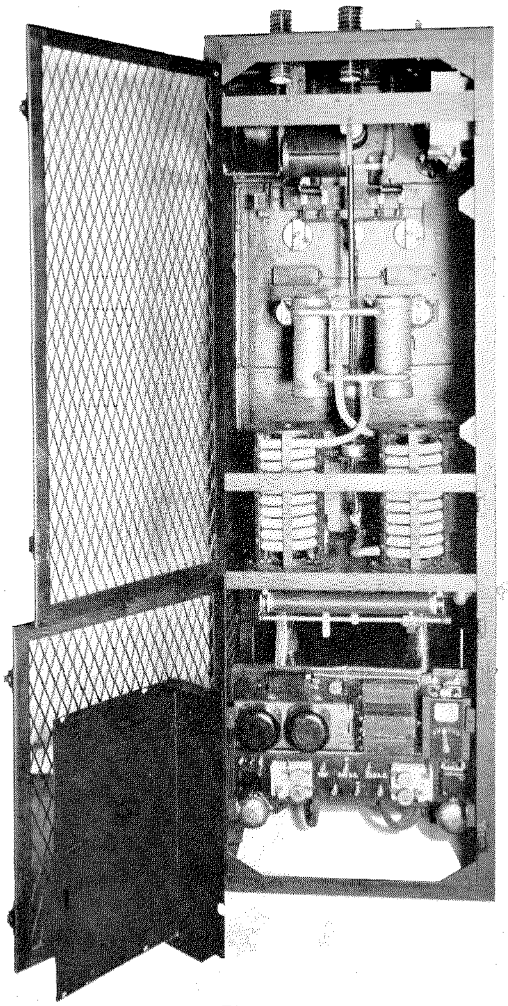


Figure 9

I am sorry I have no drawings of the first stage in which the modulated wave is produced. Figure 8 represents the front view of the 5 kw. amplifier, which raises the power from 300 watts to 5 kw. At the top are meters for measuring the currents of each of the two water-cooled vacuum tubes which are inside. Two clocks will be noticed, one of which is arranged to operate only when the filament is being burned, and the other when the plate voltage is applied. This gives a check on the life of the tubes; it is simply a refinement. In the middle is a thermometer, by means of which excessive temperature rise in the cooling water can be detected. We also have a filament alarm. In the middle of the panel are shown circuit breakers and rheostat handles to control the filament, also a glass inspection tube through which the water flows.

Figure 9 shows a rear view of the same amplifier. The two cylindrical water-jackets into which the vacuum tubes are fitted can be readily seen. Water flows through these, and through the hose which is arranged in a spiral form; tap-water is ordinarily used, although sea-water could be used if desired. Only a small amount of water is required to cool the tubes and the temperature is regulated by the flow of water. A water flow alarm, which operates if the flow of water is cut off for any reason is provided. The length of hose used is necessary to insulate the tubes from earth, as we are operating the anodes of these tubes (which are, of course, electrically connected to the water jackets), at from 6,000 to 10,000 volts above earth potential. It is, of course, much more convenient to operate with the anodes rather than the filaments at a high potential. The insulation between the water jackets and earth is the column of water in the hose.

Figure 10 shows the vacuum tube that we are using. It consists of a copper anode, to which is sealed the glass cylinder. This seal will hold a vacuum between —190° C., which is the temperature of liquid air, and + 350 C., the boiling point of mercury. No trouble of any kind has been experienced with these copper-glass seals. Inside the anode is the grid structure, a helix, and inside that again the tungsten filament, which takes about 25 amperes. For heating the filaments we use alternating currents, and take it from the secondary of a small transformer which is in the amplifier. The terminal bringing

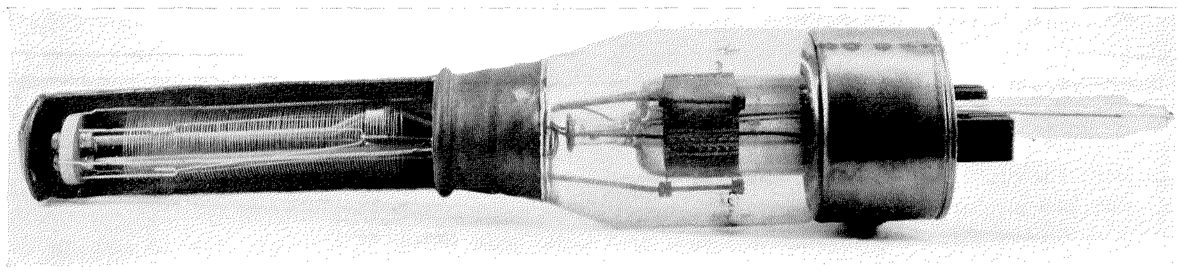


Figure 10

out the grid lead and the cap mounting the filament terminals can be clearly seen in the illustration.

The amplifier shown in preceding illustrations raises the power to 5 kw. Figure 11 shows one of the amplifiers which raises the power to its final level, and was prepared before the assembly was finished. There are 10 water jackets,

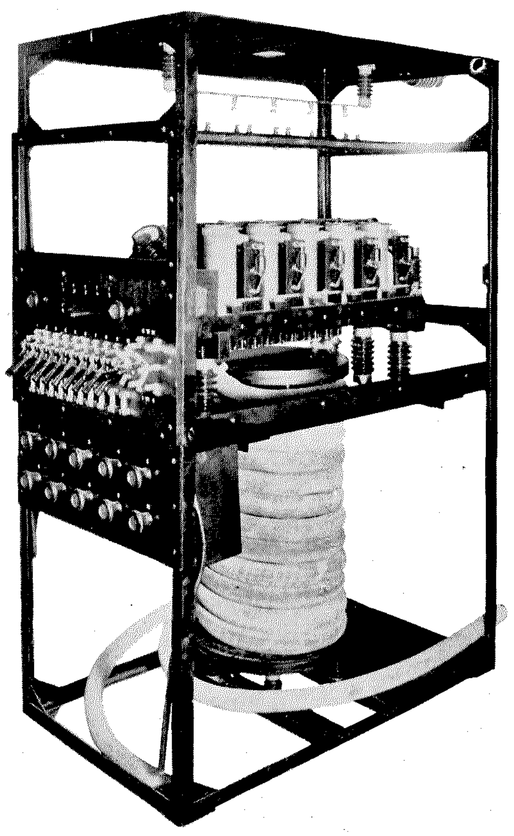


Figure 11

mounted in two rows of 5. The hose serves exactly the same purpose as in the other amplifier, namely: to insulate the water jackets and the anodes from earth. The switches mounted on the front panel allow us to connect a meter into any one of the filament circuits of the tubes. Below the switches are filament adjusting rheostats. The whole assembly is mounted in an iron frame, the front of which is about the size of an ordinary door, and about four feet in depth. Each of the tubes deals with 10 kw. and this device when used as an amplifier will amplify a sine wave current to 100 kw. With two of these amplifiers in parallel, a capacity of 200 kw. is, of course, obtained.

Figure 12 gives a view of the same apparatus after installation at the station of the Radio Corporation at Long Island. The thermometer indicating the temperature of the cooling water can be seen at the top of the panel.

Figure 13 is a side view of the same apparatus. The device for controlling the flow of water and automatically shutting down the circuit if the water stops, can be seen in this view.

There is no illustration available of the apparatus used to receive this transmission, but it is extremely simple, consisting of a receiving set operating from a square loop comprising of 50 turns of wire. The loop is earthed in the middle and is about 6 feet square, the voltage being applied to the grid of the receiving tube from half of the coil. The reason for this is, of course, that an ordinary loop is not only a loop but a vertical antenna, so that greater directional effect is obtained if we eliminate the vertical antenna part of the reception. That is done by making the two halves of the loop operate in opposite directions as far as vertical effect is concerned, and connecting the grid and filament of the receiving tube across only one half of the coil. This arrangement produces very sharp directional characteristics, as compared with the older method of using the full loop across the receiving tube.

Now, what travels across the ocean is only one side band of this modulated wave. It has been explained, by analogy, that if we tried to detect this alone we would get unintelligible speech, because all the frequencies will be doubled; therefore, before we attempt to detect this, we must reintroduce the carrier frequency component; we must reintroduce the first frequency that we generated at Rocky Point and then suppressed. The first step, therefore, is to make an oscillator which will generate a current of the frequency which was eliminated at the transmitting end, and then to couple this to the receiving circuit. Rather special arrangements are made to amplify the incoming signal and, at the same time, to secure good filter action. Finally, the combination is detected.

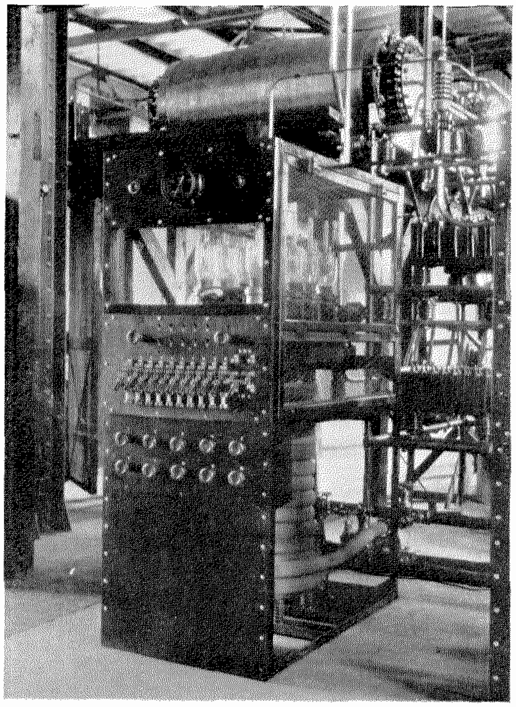


Figure 12

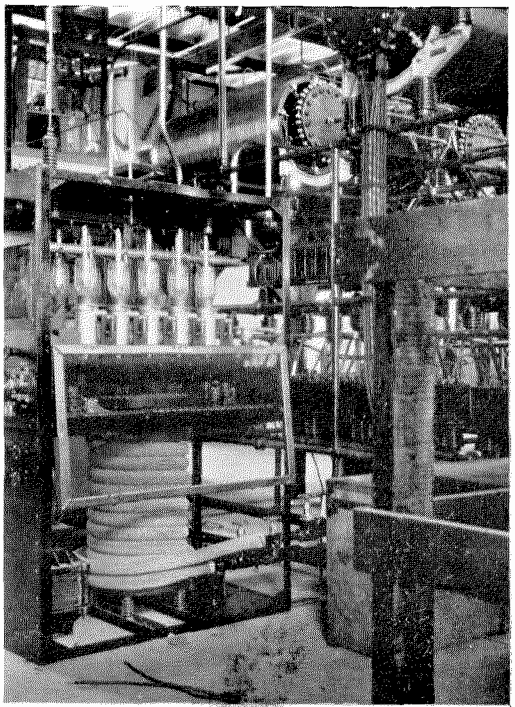


Figure 13

On detection of the single side band and the carrier we get the original speech. Theoretically, the quality would be much better than would be the case if we transmitted both side bands without the carrier, because if we transmit both bands the two bands beat and interact with one another in the receiving set, and tend also to produce double frequencies. If, therefore, we can maintain the frequency of our local oscillator constant we can, as experience on open wire "carrier" circuits in the United States has shown, get better quality than if we transmitted the complete modulated wave.

It is perhaps worthy of mention that this system of transmission, of sending out only one side band, is commercially in use in the United States on the carrier telephone circuits. It is used there, not to save power because in the case of land lines this is not of great importance, but to cut down the crosstalk, which would otherwise be caused by the powerful carrier component, and also to secure a greater number of conversations in a given frequency range, because on an ordinary open wire circuit, there are also only available about 30,000 periods.

After detection in the receiving set, the resultant output of the detector is then, of course, amplified as much as may be necessary. This depends on what we are going to do with it.

The receiving set used was built primarily for another purpose: it was set up at New Southgate in order to make measurements of the strengths of signal received on this side, and also the noise—the unavoidable electrical disturbances which are always present at every receiving station.

Now, in engineering any communication system whatever,—whether radio or wire or speaking tubes, etc.—in order to secure intelligible speech at the receiving end, it is absolutely essential that the strength of the signal received should be greater—perhaps ten or fifteen times greater than any noises which arrive at the receiving station. It is perfectly obvious that if we only get a very weak signal—perhaps only a little louder than the noises—it is of no use whatever to amplify, because we amplify the noises as well. It is useless to amplify a weak signal, unless the noise level is so much below the signal level that the result will be intelligible.

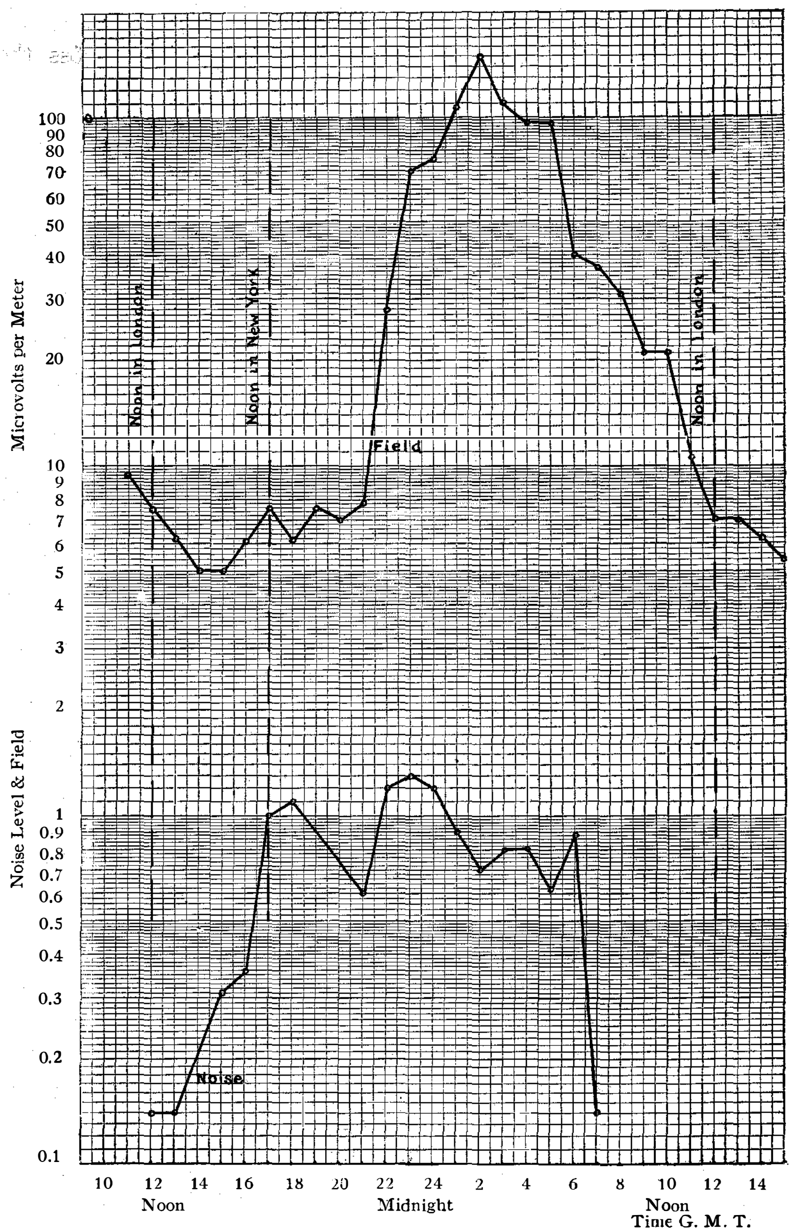


Figure 14

The first step, therefore, in the intelligent design of a trans-atlantic radio telephone circuit, is to determine how much signal we get over here per kw. in New York, and, secondly, how much noise we get. If we secure data of this kind over one year (which is about the cycle for noise, and also for transmission) then it is, of course, a very simple matter to determine how much power we must have for every day in the year at New York. If we know that, we can find out how much it costs, and then we can tell whether it is commercial to do it. No one can tell before that. The first step, therefore, in the design of such a system is to secure this fundamental information.

For the purpose of measuring the noise, we make use of the receiving loop, and compare the signal, which is coming in with a known signal which we introduce.

Figure 14 gives some of the results of these determinations. What we want to measure at the receiving station is electrical force or electrical intensity. We want our results to be independent of the kind of antenna used, so we measure the electric field strength in the ether just outside the antenna. The normal unit for this is volts per centimetre, but this unit is rather inconvenient, and accordingly we use microvolts per metre; that is, absolute or C.G.S. electro-magnetic units. The results which have been plotted in Figure 14 are in terms of microvolts per metre in the ether. It is necessary to remember, in examining this curve, that a logarithmic scale is used for the field (ordinates); there would otherwise not be room to plot them on the paper. The times indicated are Greenwich mean time. The upper curve represents the strength of signal which we get about this time of the year for every hour in the twenty-four.

The curves are almost exactly alike from day to day at this time of the year. It will be noticed that from 12 hours to 21 hours, that is, from noon to 9 p. m.—the signal strength is about 6 or 8 micro-volts per metre. These times correspond to a period when it is daylight the whole way across the Atlantic, and when the actual transmission is the poorest. It is the time when the field intensity is lowest. What signal we get depends, of course, upon the noise. At about 9 p. m. the signal strength begins to increase. It rises from 8 to about 80 units; that is, about 10 times. It continues to increase until at 2 o'clock in the morning it is up to 150 micro-volts per metre; that is, 19 or 25 times what it was in the afternoon. That is a perfectly normal sort of thing with radio transmission, and it has an extremely important bearing upon the design of radio transmission systems, as I shall explain later. During the time in which the field is a maximum, it is night all the way across the ocean. We then begin to get daybreak here on the east side of the circuit, and, since daylight transmission is poorer than night transmission, the electric field begins to come down, and finally at noon it is back to about where it was at noon the previous day.

It will be noticed that the difference is from something like 6 micro-volts per metre up to about 150—a variation of as much as 25 to 1 in the electric field.

At the same time, we have measured and plotted the noise which is tending to obscure this transmission. If we had no noise, we would not care if we only got one-tenth of a micro-volt per metre, because nowadays we can amplify almost without limit. We do get noise, however, so we have to have bigger signals. The noise at noon on this particular day—and this is rather typical—was about two-tenths of a micro-volt per metre, as compared with 8 for a signal; in other words, a ratio of 40 to 1 of signal to noise, which allows perfectly good speech in spite of the fact that our signal is not strong. As the afternoon goes on, the noise increases until finally, at 5 p. m., we have 1 micro-volt per metre of noise and only 8 micro-volts per metre of signal. This means that the result will be unsatisfactory; it is equivalent to a very poor telephone circuit.

The noise remains at this value all through the night, but the signal strength goes up, so that later we get very good conversation. The signal strength decreases again towards 6 o'clock in the morning. If a curve showing the ratio of signal strength to noise were plotted, it would indicate that we could get reasonably intelligible talk for 12 to 14 hours a day at this time of the year, using 60 kw. at New York. For the remaining 10 or 12 hours a day we would not get satisfactory talk, and, at certain times, especially about 6 o'clock at night, we would get practically no talk at all.

There is a formula which gives the signal strength at a given distance and a given frequency, due to a given current in a transmitting antenna of given effective height. That formula contains two terms, the first a term which gives us the spreading-out effect, the ordinary inverse power law of spreading, and the second, multiplying the first, which gives us what is known as absorption due to ionisation of the atmosphere, or something of that kind. The absorption factor for trans-atlantic communication at 60,000 periods (about what we are using) is 30 to 1. matter of fact it does so. This is for long waves—5,000 or 6,000 metres.

Figure 15 shows some curves which were obtained in connection with our ship to shore telephone work of connecting the Bell telephone system in the United States with ships, so that from the ship one can carry on a conversation with anyone in the United States. This is done

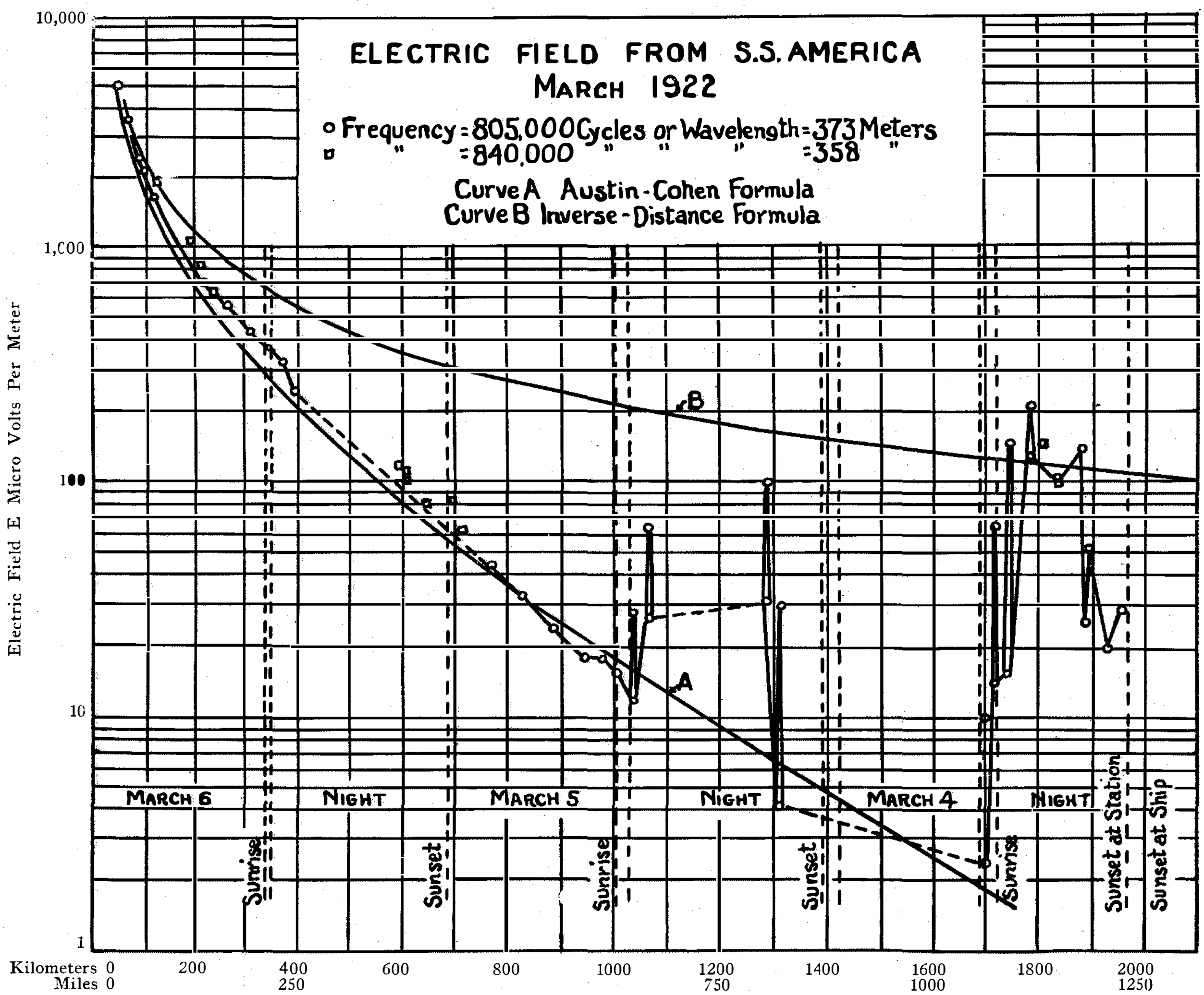


Figure 15

The difference between day and night transmission is represented by a clearing up of this absorption; that is, the normal field is obtained in the daytime, according to this formula, and then, if the absorption is lifted, the signal increases by an amount equal to the absorption factor. For example, this signal ought to increase 30 times between day and night, if that formula were absolutely accurate, and as a on a short wave length, viz: about 400 metres, because we want to work over only two or three hundred miles. There was such a telephone set on the S.S. "America," and this is a record of the field strength obtained, as measured in New York as the "America" came from France to New York. The ship is going towards the left-hand side of the figure. Two curves are plotted. Curve A, represents the so-called Austin formula, referred to previously, which should give the daily over-water values of received field. Curve B is the same formula without the absorption factor, and theoretically—perhaps that is too strong, but it is plausible, at least—the difference between day and night transmission ought to be equal to the difference between those curves.

When the ship is very close, only about 100 miles or so away, the observed values (which are marked by circles), coincide with both curves, as they should do, as it is daylight. During the last night, before arrival, there is very little change. During the second day, before arrival, you will notice that the observed values fall almost exactly along the theoretical curve. Then we have the second night before arrival, here we begin to get some effects of absorption. There are freak effects; for instance, the field suddenly rises from 10 micro-volts per metre to 70, and varies irregularly, finally going up, near the beginning of the second night, to 100 micro-volts per metre, as compared with a normal daylight measurement of about 6. On the third day before arrival the ship is about 900 miles away. There are not many observed points plotted, but as a matter of fact we obtained them in other curves. They fall almost exactly on this curve of the Austin formula until it is night, and then we begin to get tremendous variations, due to the lifting of the absorption. In other words, we get a variation from 1 micro-volt per metre to 200 micro-volts per metre the third night before arrival, when it is 1,100 miles away. This is all over water. There is a ratio of 200 to 1 in the day and night values. One other point worthy of mention which is not shown by these curves. These remarkably high values occur almost periodically, that is to say, you are likely to have 200 micro-volts per metre for 10 seconds and then 1 micro-volt per meter for 10 seconds, so that it is quite impossible to control the amplification of the circuit.

We have plotted a number of these curves, and this is typical of short wave transmission as compared with long wave. The conditions are unusually favourable because all the transmission is over water.

The values will be very different during summer. In summer, the noise goes up tremendously and the transmission goes down somewhat, so that in order to determine how much power will be required it will be necessary to take these measurements over a complete cycle, which is one year. We expect, therefore, to continue these observations until next September. The worst period is July and August. Once we are through the worst period, conditions will begin to repeat themselves again. We shall therefore carry the results from July to September inclusive, so that we can determine how much power will be required at New York to maintain a commercial circuit. Whether or not such a circuit will be built depends on other than engineering considerations. We hope to have, next year, information which will allow us to design intelligently a commercial radio telephone circuit when and if it is demanded.

Economics in Engineering

By FRANK GILL, O. B. E.

European Chief Engineer, International Western Electric Company

(This paper was presented at a meeting of the Student Section of the British Institution of Electrical Engineers in London on March 9, 1923.—EDITOR.)

IN my presidential address to the Institution of Electrical Engineers, I made use of the following words:[1]

"But I do not remember an instance of a student being familiar with the economic aspect of engineering studies, nor of one who had any idea of how to tackle a problem of engineering economics. Yet that question of economics is the fundamental problem of the engineer."

Accordingly it seemed incumbent on me to talk to you mainly about this matter, since if it is so important, and if it is not being generally treated in the schools, I must do what I can to ventilate the subject. I have spoken on this line of thought to several of the Local Sections, but have not so far been challenged as to the accuracy of the statement that students do not appear to be taught this matter, though it is not to be expected that the statement is universally true. Frederic Bacon, Professor of Engineering at University College, Swansea, has recently stated:[2]

"During and since the War labor and economic troubles have been so acute that it is incredible that our educational system for training engineers can much longer blink the fact that engineering is not merely concerned with materials and design, but with finance, economics, labor, materials and design."

So that it may perhaps be accepted that the accusation is in fact sufficiently accurate.

Engineering is in reality a three dimensional work since it involves considerations arising out of the physical properties of materials, the economic problem and the psychology of those doing the work, and these three of necessity react on each other. But the one to be referred to now is the economic problem.

What do we mean by economy and economics?

Originally the word referred to the management of the household by a frugal use of money; we may say it differs from parsimony which implies an improper saving of expense. Until recently it seems not unfair to say it was concerned solely with the subject known as Political Economy, which has been defined in Professor Marshall's "Principles of Economics" as "a study of man's actions in the ordinary business of life; it inquires how he gets his income and how he spends it." The engineer, however, has given a new meaning to the word (though, of course, it is part of the larger subject) since he has applied its processes to help him in selecting plant and methods for achieving what he wants to do.

The engineer's job is not only applied physics; it is that, of course, but it is more, for that by itself would neglect the important element of cost. There are three very important sections to his work. These are:

Requirements in which he sets out as exactly as is practicable just what is to be done and the limits of accuracy to be observed; this is important, because it is the absence of strict requirements which so often permits unlike things to be quoted as alternatives.

Design in which he arrives at alternative methods of filling the requirements.

Selection in which he chooses which of the alternative designs (each of which will meet the requirements), it is best to employ.

For how often it happens that when a piece of work has been constructed according to the engineer's designs, the management can only operate on a margin, important no doubt, but the question as to whether or not the work shall be profit earning has been settled when the design was made. For consider, it is settled, always within margins, what shall be the money payable as a return on the capital employed; the money required to offset wear and tear and obsolescence; the money required for maintenance; the cost of feeding the plant and the cost of such matters as insurance, taxes and overhead charges. It is almost impossible for efficient management to make profit out of a poor engineering job.

If this is so, then the engineer is vitally concerned with the profit made by his firm and he

[1] Presidential Address—Institution of Electrical Engineers, Vol. 61, page 2, December, 1922.

[2] "The Importance of Economics," *Western Mail*, February 23, 1923.

cannot stand aloof as one connected only with the scientific and mechanical sides of the business; he is, and must regard himself as very much concerned with the question of profit earning.

So we see that one important part of the engineer's work is selection from among alternatives, any of which will achieve the result desired. This part of his work may in fact be illustrated by Figure 1. This curve shows a

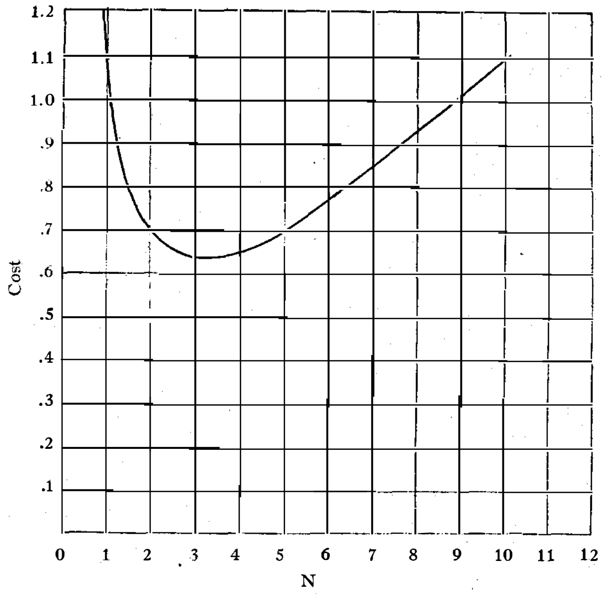


Figure 1

number of alternatives (N) *any one of which gives the same desired requirements,* plotted against the cost. There is invariably a bottom point to the curve and the engineer is always seeking that point as it shows him how to do his work at least cost.

Now what do we mean by least cost? Let us get right back to the origin so as not to be misled by the names of tokens, for though it is convenient to consider cost in terms of money, yet really money is only a token. When man works he produces something—let us assume he grows and harvests potatoes—if he is diligent and thrifty he does not consume all the potatoes he produces and the spare potatoes are his capital. Because he has these spare, other men are anxious to work for him, for example, to grow corn to exchange for his potatoes. In fact, directly he consumes less than he produces, he becomes a capitalist able to call on others for their work. The capitalist is wanted and not to become one indicates an unthrifty spirit.

Since it is inconvenient to trade by barter, that is, exchange of goods, money, the common denominator, which goes into all things commercial, was invented, and still later credit which in large transactions replaces money. But at the back of all the complex matter of trade, cost involves the expenditure of human effort and so the effort to do a thing at lowest cost means the least expenditure of human effort.

To produce a motor, for example, at lower cost, involves less effort in producing the motor and more purchasers to enjoy the benefit of the machine and so the lightening of their labors. Like mercy, "it blesses him that gives and him that takes," and rightly considered is work in which any man, even though he be an idealist, may take a pride and delight, always supposing, of course, that the work itself is beneficial to humanity.

Just here a caution is necessary. In Figure 1, we saw that at the bottom of the curve the rate of change in slope is very small and not much was gained, if in that case (N) varied between 2.5 and 4, and that it would be waste effort to push the search for least cost to its ultimate conclusion. So we get as a requirement in the engineer, the sense of the proportion of things—he must know when to stop.

Figure 2 illustrates this; obviously it may not be economical to push the quest for efficiency to the last, seeing that in the illustration the cost of obtaining additional efficiency becomes so burdensome.

If in this Figure 2, we read on the right hand scale "Return in £" instead of "Efficiency %," then it is seen that for the expenditure of the first £1 in cost we get an increased return of £8; for the next £1 we get a return of £4; then £2, then £1, then £0.5, and so on. But at the third £ cost we reach the point where an additional cost of £1 will return only £1 and after that the return will be less than the cost.

This curve illustrates the law known as that of Diminishing Returns and the point of Negative Return.

We come then to this: the engineer's job is the wise utilization of money and in achieving this he has to take many things into consideration.

Assume a reservoir is to be made and a dam constructed at the end of a valley; theoretically, given enough labor and material, anybody can do this; it is only necessary to heap in sufficient of the right kind of material, and the job is simple enough. But to build the dam rightly at the lowest cost is not by any means a simple job.

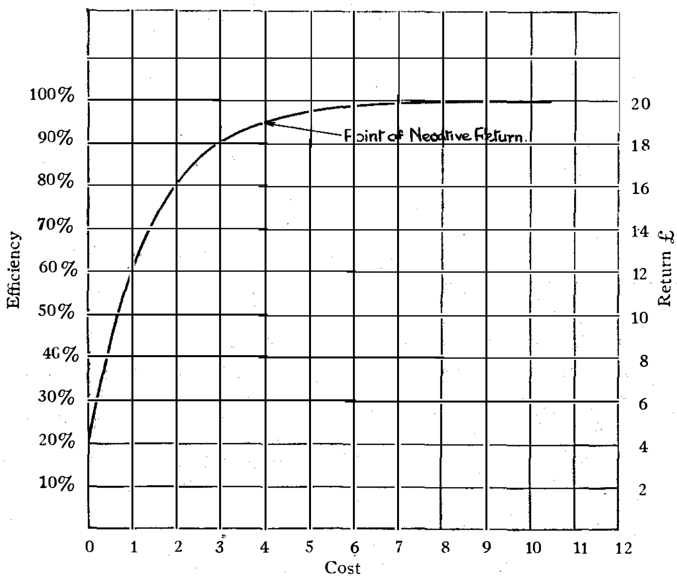


Figure 2

So we have to consider "cost" and that needs definition. For our present purpose there are two costs, and which of the two is meant should always be made clear and they must be considered separately. They are *First Cost* and Annual Cost or, since it is better to avoid the use of the same word, *Annual Charges*. Frequently these two are mutually antagonistic and it is necessary to settle the principles which are to govern selection. For example,[3] "Assume a situation in which there is as yet no plant installed and let there be two alternative ways of achieving the results required, *A* and *B* as below:

	Alternative A *First Cost, £10,000*	*Alternative B* *First Cost, £15,000*
Annual Charges	£	£
Return on Capital..	500	750
Depreciation.......	600	450
Maintenance.......	500	300
Operation.........	900	600
	2500	2100

Annual Charges for A = £2,500
Annual Charges for B = £2,100

"It is evident here that although alternative *B* requires more capital, yet it is worth while to expend the greater sum because the annual charges are less, so that either a reduced sum can be asked for the product, or since the results achieved are the same, the cash for the product can be the same and an excess profit made."

If, therefore, capital is available and if all risks are properly included in the computations, it is usual and correct to select on the basis of Annual Charges rather than on the basis of First Cost. If capital is not available it may be necessary to select on the basis of first cost, but that is equivalent to *force majeure*, not selection.

If then selection is to be made on the basis of annual charges, it is necessary to have these annual charges as accurate as practicable and they may not be lightly treated by rough approximations which may lead to serious error in selection. Now obviously the figure of 10% for capital charges which is constantly used in the few engineering discussions on economics is just such a rough approximation, which cannot possibly be true for all the cases of varying life and conditions for which it is used. In the example just given, if capital charges (i.e., return on capital plus depreciation), had been taken at 10% the total annual charges for *A* and *B* would have been equal, and the choice would wrongly fall on Alternative *A*, because of the lower first cost. The only virtue which the 10% possesses is that it is easy to calculate.

Let us look then at the items which go to make up the annual charges and see on what they depend.

Return on capital outlay, frequently termed interest; this must be treated as a charge because no engineer, in the absence of special circumstances, is justified in constructing plant which will not pay an adequate return on its own first cost. The amount of this return will depend upon the amount of capital expended (which may include charges to capital during construction), also upon the credit of the owner of the plant in the then state of the money market. It may, for example, be 4½, 5, 6 or 8% per annum and therefore, it may vary according to the credit of the one for whom the work is to be constructed

[3] "Principles Involved in Computing the Depreciation of Plant," by F. Gill and W. W. Cook, Institution of Electrical Engineers, Vol. 55, page 138, 1917.

and the frequency and amount of further capital expenditure will also affect it.

Depreciation. I define this as (1) "renewals" being provision for the diminution in value of plant in place, by reason of causes *outside* the control of the owner (e.g., age, wear, accidents), and (2) "improvements" being provision to enable him to take the plant out of commission before its physical life is exhausted, that is, by reason of causes *within* the control of the owner, sometimes referred to as obsolescence.

The money required annually as provision against depreciation will depend upon the life of the plant chosen, which in turn depends on the conditions, under which it will work and the kind of plant selected. The credit of persons will also be involved since the money put away each year should earn interest. Unless it is so put away in some form or another, the growing financial liability may become overwhelming. The amount will also depend upon the method of treating the provision for depreciation; but since this part of the subject is too large to be dealt with now, it will be assumed, for the purpose of this discussion, that the sinking fund method will be used. Note that the depreciation provision is to replace the capital expended, not to replace the plant. This may cost more or less.

Taxes. These will largely depend on political decisions and on whether the owner is subject to taxation.

Insurance. This will largely depend upon the kind of plant used and upon whether or not any owner, in fact, recognizes his liability to provide for insurance as an annual charge.

Administration. This will depend upon the plan of operation and organization followed by each individual owner of plant.

Maintenance. This will depend upon the degree or quality of maintenance desired by the owner, upon the kind of plant constructed, and upon its situation.

Operation. This will depend upon the kind of plant employed but may also be affected by the individual conditions applicable to each job.

In all these cases there is the common element of the employment of money during a period, and so the conditions under which money may be employed must be part of the engineer's knowledge. This leads us to the matter of interest which may be put briefly, somewhat as follows—money, being merely credit, may not be held for nothing; the mere possession of money or of materials and plant for which money might be exchanged, involves a continuous charge so long as the possession lasts.

If I put say £100 away in a stocking and leave it there safely and draw my £100 from the stocking in 10 years' time, it has cost me something. For if the market rate for money is say 4% per annum that £100 if invested at 4% compound interest for 10 years would have grown to £148, and so the policy of putting the money away uselessly has involved the loss of £48.

If the market rate had been 6% per annum the loss would have been £79, and, of course, if the time had been longer, say 20 years at 6% per annum, the loss would have been still greater, viz: £220. Parenthetically, one may say that it was this failure to use wisely the credit placed at his disposal which brought down the rebuke on the head of the unprofitable servant.

We may illustrate this matter by considering it somewhat in the light of financial perspective.

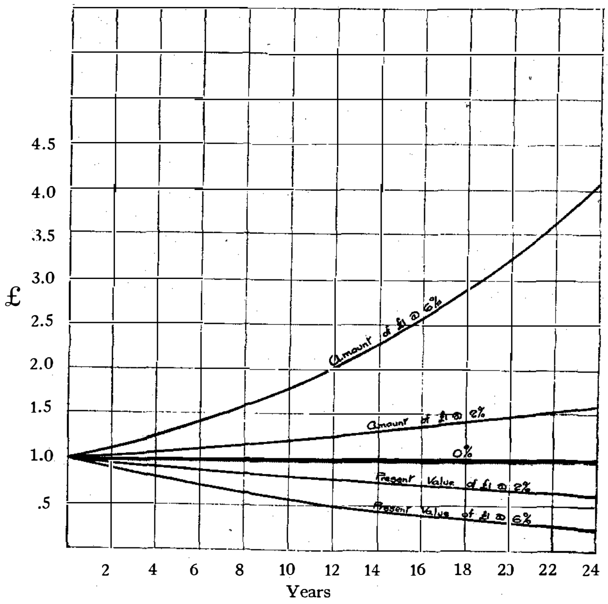


Figure 3

Figure 3 shows the amount to which £1 will accumulate if it earns interest for a number of years and also its present value if its payment is deferred for a number of years. It will be obvious that an expenditure of £1 First Cost now is more serious than an expenditure of £1 First Cost deferred for a number of years. Hence it would not be correct to add today's First Cost and deferred First Cost; they must be brought to some common time basis, generally the present time. As an example, if a scheme involves the expenditure of £100 now and £100 in 10 years' time the total present value of the expenditure (assuming 6% per annum) is

Now	£100
Deferred—100 x .56	56
Total Present Value	£156

In the same way Figure 4 shows the amount to

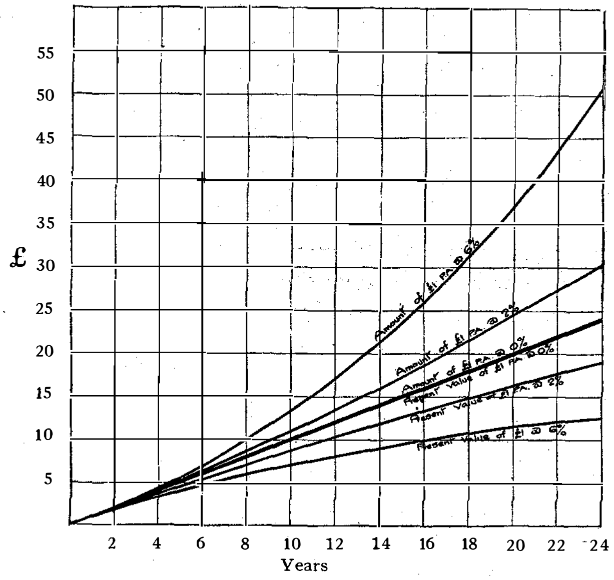


Figure 4

which a payment of £1 per annum (called an annuity) will accumulate if it earns interest for a number of years and the present value of the annuity.

If £1 per annum at 6% per annum will increase in 20 years to £36.79, then it is obvious that to accumulate £1 at the end of 20 years at 6% per annum will require an annual payment of 1/36.79= £.027 and so sinking fund tables are formed, being the reciprocal of the amount of £1 per annum at the various rates of interest.

Figure 5 illustrates sinking fund payments, both if interest is disregarded and if taken at 6%; there is shown also the ratio between the two. Now in engineering computations of depreciation, interest is frequently disregarded, but it must be remembered that accurate annual charges cannot be ascertained unless the rate of interest, appropriate to the occasion, is taken into account.

Perhaps enough has been said to proceed now to illustrate, by reference to cases, but the treatment must be very approximate in order to cover the ground.

1. First of all, let us take a case of opening a street in which to lay ducts to contain cables. The rate of growth has been estimated, the cost of breaking up and restoring the street surface is known; also the excavation cost and how it varies with the number of ducts; the cost of the ducts laid; the financial rates such as interest, depreciation, etc. Suppose we require to have 6 ducts now and 3 more later on, then our problem is, shall we lay the additional 3 ducts now or wait till they are required? We may approach this roughly as follows: Assume the cost of a trench containing 9 ducts is 45/— per yard run, the cost of the same with 6 ducts is 32/—, therefore the additional cost of the 3 ducts if laid now is 45−32=13/— per yard. Assume also that the cost of 3 ducts laid independently

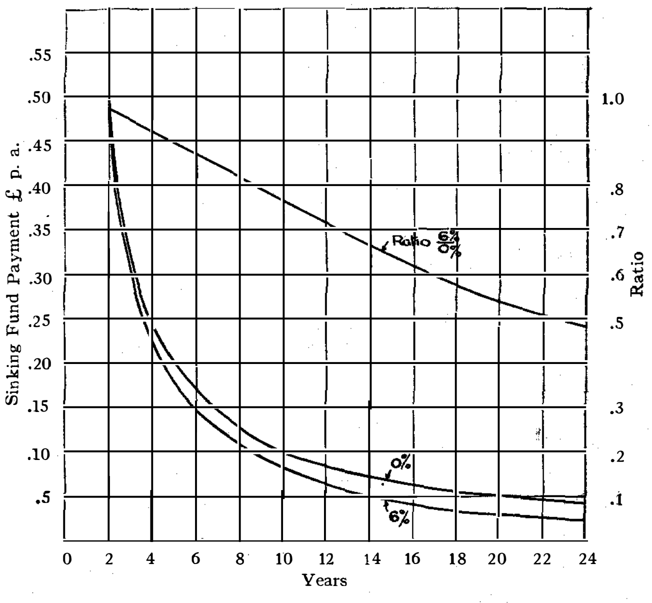


Figure 5

is 22/— per yard run. Further assume that the full charges on capital are 8% per annum.

The extra cost *Now* per yard is	13/—
The extra cost *Deferred* per yard is	22/—

The ratio of these is 13/22=0.59. From the 8% interest tables we see that 0.59 is the present value of £1, 7 years hence, so that if the growth is such as to require the extra ducts within 7 years it is economical to lay them while the ground is open. Just what is the most economical period to plan for, and there is such a period and it is important, cannot be treated in such a hasty manner.

2. You may say this is just common sense and so it is, but the sense is not common. To demonstrate this, let me quote Professor Miles Walker from his book on "Specification and Design of Dynamos," 1915, where on page 495 et seq. he says:

"We may wish to build the generator as cheaply as possible, using the smallest amount of wire that will give us a temperature rise not greater than the guaranteed temperature rise.

"We may be ruled by considerations of efficiency and settle the number of watts which are to be wasted in shunt excitation.

"A large number of buyers will buy the cheapest machine that appears to be good enough for their purpose. Other buyers, on the other hand, recognize that very often a more expensive machine of higher efficiency will save more in the year than the interest on the extra cost. With power at one halfpenny per unit, a kilowatt of twelve hours a day for 300 days in the year will cost £7.10.0 per annum. Capitalizing this at 10% we get £75. It would in many cases be worth while for a buyer to pay £75 more for a machine which will save him one kilowatt in the shunt excitation.

"In the machine worked out on page 489 (75 kw. 525 volt, 25 cycle, 750 R. P. M.) the loss in the shunt coils and rheostat is 820 watts. The weight of copper is 64 kilograms. This is almost the minimum weight we could use if we are to meet the temperature guarantees. It would be good policy to increase this weight and make a saving in shunt losses if the buyer would recognize the fact, and pay a greater price. There is room for another 1,500 turns, which would reduce the losses by 250 watts. This, on the above basis of calculation, could be capitalized at £19, and yet the cost of the extra 1,500 turns would not be more than £8. Yet so keen are many buyers to buy the cheaper (First Cost) machine, heedless of small differences in efficiency, that the practice of using the least possible quantity of copper pays from the manufacturer's point of view.

"The same want of regard on the part of the buyer for small differences in efficiency leads many manufacturers to use ordinary dynamo steel of good quality at say £11 per ton rather than alloyed steel at £25 per ton. In the present case, with ordinary iron, the iron losses work out at 840 watts, whereas with alloyed steel they could be reduced certainly to 600 watts. The saving of 240 watts is worth about £18, and the cost of the alloyed iron would not be more than £5.

"Some buyers are beginning to recognize these facts, and the future may see a very great increase in the efficiency of small generators and motors."

One is tempted to ask where were the buyers educated that they should have their minds so set upon first cost as not to recognize that the apparently dearer machine is really the cheaper one.

But this matter of 10% capital charges never appeals to me, so it will do no harm to take the case more in detail. Let us assume the following, using the same figure of £8 as the increased first cost:

	Case A		*Case B*
First cost	£352	£352+8=	£360
Scrap value 15%	52		54
Depreciable amount	£300		£306

The return on capital being taken at 6% per annum, the sinking fund to redeem the depreciable amount will also be at 6% per annum, and let the life be assumed at 15 years.

Therefore our annual charges will be as follows:

	Case A	Case B
Return on Capital 6%	on £352 =£21.1	on £360 =£21.6
Sinking Fund 6%	300 x 0.043 =£12.9	306 x 0.043 =£13.2
	£34.0	£34.8

But by adopting the machine in Case B we are saving 0.25 kilowatt at £7.10.0 per kilowatt for 300 twelve-hour days in a year. Hence the annual charge of the machine in Case A should be increased by 0.25 x £7.10.0 = £1.9.

Our annual charges will therefore be:

Case A. Annual charge 34.0+1.9 = £35.9
Case B. Annual charge = £34.8

In other words, a saving per annum of £1.1 is effected by adopting the machine in Case B, which is £8 dearer in first cost.

Now we find that if the machine in Case B. were to cost £372 initially, that is £20 first cost greater than the machine in Case A. the annual charges would be the same in both cases. Notice that it does not "pay" to buy the machine at £20 additional first cost; that is, the additional first cost at which the two machines equate, but it does "pay" to give the additional £8 first cost, and it would "pay" to give any increased additional amount up to £20.

3. In the scheme for sanctioning loans by Local Authority undertakers, the Electricity Commissioners "adopt as a general basis the principle of sanctioning separate repayment periods determined by the estimated life of the various assets (land, buildings, plant, etc.)."

Some of the maximum periods are:

	Years
Land, freehold	60
Buildings	30
Plant and Machinery	20
H. T. Trunk Transmission Mains	40
Overhead Lines	25
Mains and Services	25
Meters	10

Presumably the period for freehold land is based upon something other than the life of the asset.

In cases where the generating plant is likely to be superseded the term is less and is usually 15 years.

I understand that with regard to steam plant the maximum loan period for turbos is 20 years and for Diesels engine is 15 years. I am not questioning the correctness of these lives when I point out (again assuming 6% interest but this time without scrap value for simplicity), that this difference in the loan period will have an effect on the economics of the matter because the Sinking fund for a 15 year period at 6% is 57% greater than for a 20 year period.

4. Let us take another and very usual kind of case, and work it out in detail.

Let us assume a 30 foot pole line 1,000 feet in length situated in a roadway. The pole line has four 8 wire arms with No. 14 iron wire for distributing purposes. It is expected that in any event this route will have to be removed from the roadway at the expiration of 6 years. The line will not carry any further arms and additional facilities can only be provided by installing a 25 pair aerial cable on this pole line. There are at present 16 pairs of wires branching off the route for subscribers' circuits (referred to below as branches) and the growth is such that a further 24 circuits will be wanted within 6 years, which then represents the ultimate requirements. When this pole line is abandoned the new distributing system that replaces it will consist of a 25 foot pole line 1,000 feet long built in an alleyway behind the houses and carrying a 50 pair aerial cable with suitable terminals.

The question is whether it would be cheaper to place the 25 pair cable on the existing pole line utilizing it for 6 years and then build the new line (recovering the existing line) or to build the new line and take down the roadway line at once. After 6 years the construction would be the same in both cases, so it is only necessary to consider the costs for a period of 6 years. The figures given as "first costs" and "annual charges" are for the purpose of illustrating the two cases only, and must not be taken as being in any way representative figures. Money is assumed to earn 6% per annum, and we work out the two cases as follows:

Case I. Existing pole line retained for six years.

Item	First Cost in £s	Annual Charges		Present Value of Charges
		%	Amount in £s	
1. Existing Plant.				
(a) 30′ poles, stays and steps	30	12	3.6	
(b) Arms and wire	50	18	9.0	
(c) 16 existing branches at £2 each	32	18	5.76	
2. 1,000 ft. 25 pr. L.C. cable including suspension strand and terminals	80	15	12.0	
			30.36	
P.V. of £30.36 per annum for 6 years = 30.36 x 4.917 (Fig. 4)				149.28
3. 24 branches during 6 years, equivalent to all deferred 3 years and existing for 3 years more, 24 at £2 each	48	18	8.64	
P.V. = A.C. x P.V. 3 years x P.V. 3 years deferred = 8.64 x 2.673 x 0.839 (Fig. 4) (Fig. 3)				19.38
4. Transfer Loss upon recovery of pole route, cable and branches 6 years hence, say £125 at 0.705 (Fig. 3)				88.13
Total P.V. of all charges				£256.79

Case II. Build new line and take down existing pole line at once.

Item	First Cost in £s	Annual Charges %	Annual Charges Amount in £s	Present Value of Charges
1. Erection of 25′ poles and stays	21	12	2.52	
2. Erection 1,000 ft. 50 pr. cable, suspension strand and terminals	110	15	16.5	
3. 16 existing branches at £2.	32	18	5.76	
			24.78	
P.V. of £24.78 per annum for 6 years = 24.78 x 4.917 (Fig. 4)				121.84
4. 24 branches during 6 years equivalent to all deferred 3 years and existing for 3 years more, 24 at £2	48	18	8.64	
P.V. = A.C. of P.V. 3 years x P.V. 3 years deferred = 8.64 x 2.673 x 0.839 (Fig. 4) (Fig. 3)				19.38
5. Transfer loss on route taken down now say £66				66.00
Total P.V. of all charges				£207.22

From these calculations we obtain the following figures:

Case I. Present value of Charges............ £256.79
Case II. Present value of Charges............ £207.22

Difference in favor of Case II........... £49.57

Therefore, it is cheaper to abandon the existing roadway line at once.

5. Another illustration, and one of a kind which may affect the young engineer before he comes to the day of big things, is taken from relay design. When relays have to remain operated for considerable time the annual power charges become important and the design must be such as to give minimum annual charges. In Figure 6 is shown a group of curves for a type of relay and these show how nearly the minimum annual charges have been attained for a certain standard type, whether the relay, without any charge whatever, is in operation from 60 to 600 minutes per day. Because of varying conditions in different places relative cost figures are shown; the main points are, the principle that even apparently simple apparatus design requires the application of economics, and that this illustration is taken from just the kind of work on which the young engineer is likely to be engaged.

Let us refer to one more illustration of a system in which certain definite results are to be reached but which may be achieved in several alternate ways. Obviously there will be some relation between the money which may be spent on one part and that which may be spent on another part so as to obtain the lowest total cost; in other words, we obtain a balance or equilibrium between the relative costs, and as previously stated these costs may be analyzed from the points of view of both the First Cost and Annual Charges.

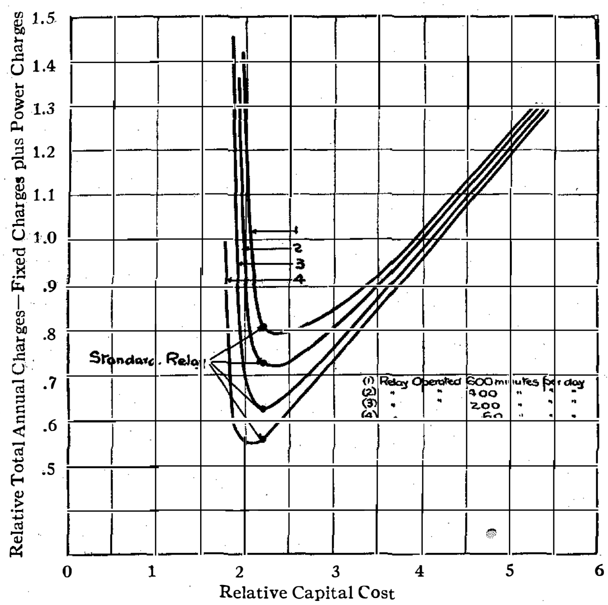


Figure 6

In engineering any work, and perhaps particularly in engineering any system, it is impossible to do it economically unless market prices are known. For with the market in one state it may be profitable to spend more money on say iron and less on copper or vice versa and the determination of this cannot be made without prices. When markets are steady, standard prices can be used for long periods but when unsteady then the engineer must obtain prices before he can select.

I do not believe that courses of study are necessary to treat this matter in the schools. It rather requires an attitude of mind on the part of the teacher, in order that this kind of treatment shall be applied sometimes to the problems dealt with. One great objection to the present method is that because students do not get this training at College, they have to acquire it either by their own efforts or by the aid of men in practice and not by the aid of skilled teachers.

It is sometimes suggested that these questions of Annual Charges are after all matters of accounting and are not really of interest to the engineers. That this view is entirely wrong is at once seen by considering the separate occasions on which these charges are important, thus:[4]

"(a) Before plant of any magnitude is constructed it is necessary to ascertain which of alternative plants is the economical one to employ for the purpose.

"(b) Either before construction, or soon after, it may be necessary to determine the rates to be charged.

"(c) After the plant is in operation, costs have to be ascertained and profits determined.

"(d) When it is proposed to scrap any plant in favor of a larger or more efficient type, it is necessary to compute the savings which will be effected and the loss of capital involved. Depreciation enters into both calculations.

"(e) In the event of a sale of plant on what are known as 'tramway terms,' depreciation of the plant has to be ascertained on one basis, and

"(f) If the business is sold as a going concern it may be necessary to compute the depreciation on another basis."

My object in bringing this matter before you is to try to interest you young engineers in a very important part of the work you will ultimately undertake. These principles are necessary even in small matters; they are vital to the safe handling of large engineering schemes involving great expenditures. Some of you may be called upon to be responsible for the wise spending of great sums of money, and to do this you must work along the principles which have been briefly sketched out here. With an adequate knowledge of engineering economics added to the more usual engineering knowledge, you may go far, increase the reputation of your profession, and do useful work; without it you are not safe guides on the expenditure of large sums of money.

[4] "The Depreciation of Plant," by F. Gill and W. W. Cook, Institution of Electrical Engineers, Vol. 55, 1917, page 167, slightly altered.

The Nature of Language[1]

By R. L. JONES

Engineering Department, Western Electric Company

PRIMITIVE man, when he wished to communicate, probably expressed himself by grimaces, vocal sounds, and gestures. Although each of these three agencies is still somewhat employed, the combination of voice and ear has been subconsciously evolved and has survived as economical, most flexible in its capacity for variation, and superior in perceptibility.

According to modern philologists, early utterances were song-like and poetic accompaniments of excited or pleasurable emotion, rich in sound and rhythm but without very definite meaning. The motives for utterance gradually changed, the process of associating sense with sound began, and speech and song came to be differentiated.

Primitive languages, in general, consisted mostly of long words with many difficult sounds. Certain exclamatory sounds came readily to designate personal feelings. Echo words, mimicing nature, came to designate natural sounds or the manner or source of their production. Names of persons and objects were an early development. Most words, however, have had a more obscure and complex history. Evolution has tended to shorten word forms and to drop sounds hard to pronounce or to hear.

As man's powers of analysis have developed language has become more flexible and capable of greater range of expression. The grammar of language in general has become simpler and more systematic.

Men in different parts of the earth have evolved differentiated languages, any one of which is now based hardly at all upon natural suggestiveness but rather upon traditional understandings gradually accumulated. Each language has its own system of elementary speech sounds. Since only a limited range and variety of sounds can be spoken, it is natural that there should be many similarities between the speech sounds of different languages. The elementary sounds of a given tongue are combined into syllables and words, and these in turn joined together into phrases to convey ideas, all according to the mutual conventions of the people who use the language.

The voice alone enabled man to communicate under circumstances where his gestures could not be seen and at distances beyond where his facial expression could be made out. In our own times the invention and development of the telephone has marked a new step in the evolution of human society, extending the vocal range of man to extraordinary degrees. Voices are hourly carried with instant speed from one end of the land to the other and it is now possible for a speaker to address at one time a million persons gathered about him or scattered at distant points. Speech is the load which the telephone system transports, and the ear is the consumer of the product. Alexander Graham Bell, inventor of the telephone, as student and professor of vocal physiology gained a deep insight into the mechanism of operation of the voice and ear before his greatest invention was made. Throughout his life he devoted himself to the alleviation of the infirmities of the deaf and the dumb. Interest in the problems of speech and hearing comes naturally, therefore, to the telephone organizations which bear his name by sentiment as well as by the needs of their practice.

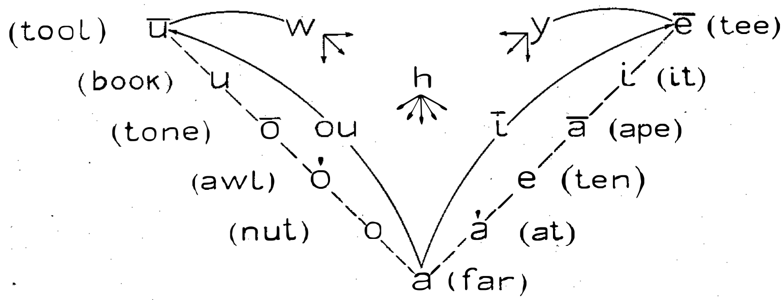
This paper refers briefly to the mechanism of speech and hearing and then describes some of the physical data of oral communication which have been obtained by investigations carried on during the past few years. A selected bibliography of published papers is attached. Much of the material brought together and summarized here has appeared in scattered form in the articles referred to.

The organs of speech are the lungs, which by their bellows-like action function as a motor element to supply streams of air which pass in and out through the vocal passages. The vocal cords, the tongue and lips, and the cavities of the mouth, nose, and throat, impress on the air flow variations which are heard as sounds. The vocal cords are a pair of muscular ledges on opposite sides of the larynx which can be stretched and brought together, forming between them a slit

[1] Presented before the following Sections of the A. I. E. E.:
Milwaukee Section—January 11, 1923
Cleveland Section—January 23, 1923
Washington Section—February 13, 1923

CLASSIFICATION OF THE SPEECH SOUNDS

1. Vowels



2. Combinational and Transitional Vowels

w - y - ou - ī - h

3. Semi Vowels

l - r

4. Stop Consonants

Voiced	Unvoiced	Nasalized	Formation of Stop
b	p	m	lip against lip
d	t	n	tongue against teeth
j	ch	–	tongue against hard palate
g	k	ng	tongue against soft palate

5. Fricative Consonants

Voiced	Unvoiced	Formation of Air Outlet
v	f	lip to teeth
z	s	teeth to teeth
th (then)	th (thin)	tongue to teeth
zh (azure)	sh	tongue to hard palate

Figure 1

of adjustable width through which the breath passes. The opening between the vocal cords is called the glottis. The flow of the breath is modulated to form the sounds of speech by the vibration of the vocal cords and by the resonant reenforcement of the vocal cavities.

Speech is composed of letter sounds usually divided into vowels and consonants, and those ordinarily used in the English language are tabulated in Figure 1. So far as possible the sounds are expressed by the letters most commonly used to designate them. In the case of some of the vowels arbitrary markings are employed to distinguish sounds which are different but which are represented by the same letter. The examples given in parentheses will help to interpret the sounds, and it is believed that for most readers the classification will be apprehended more readily with the symbols used than with a system employing entirely different symbols for each sound some of which would necessarily be new and strange. Readers familiar with phonetics will easily be able to express these sounds in the International Phonetic Alphabet or in other systems of phonetic symbols.

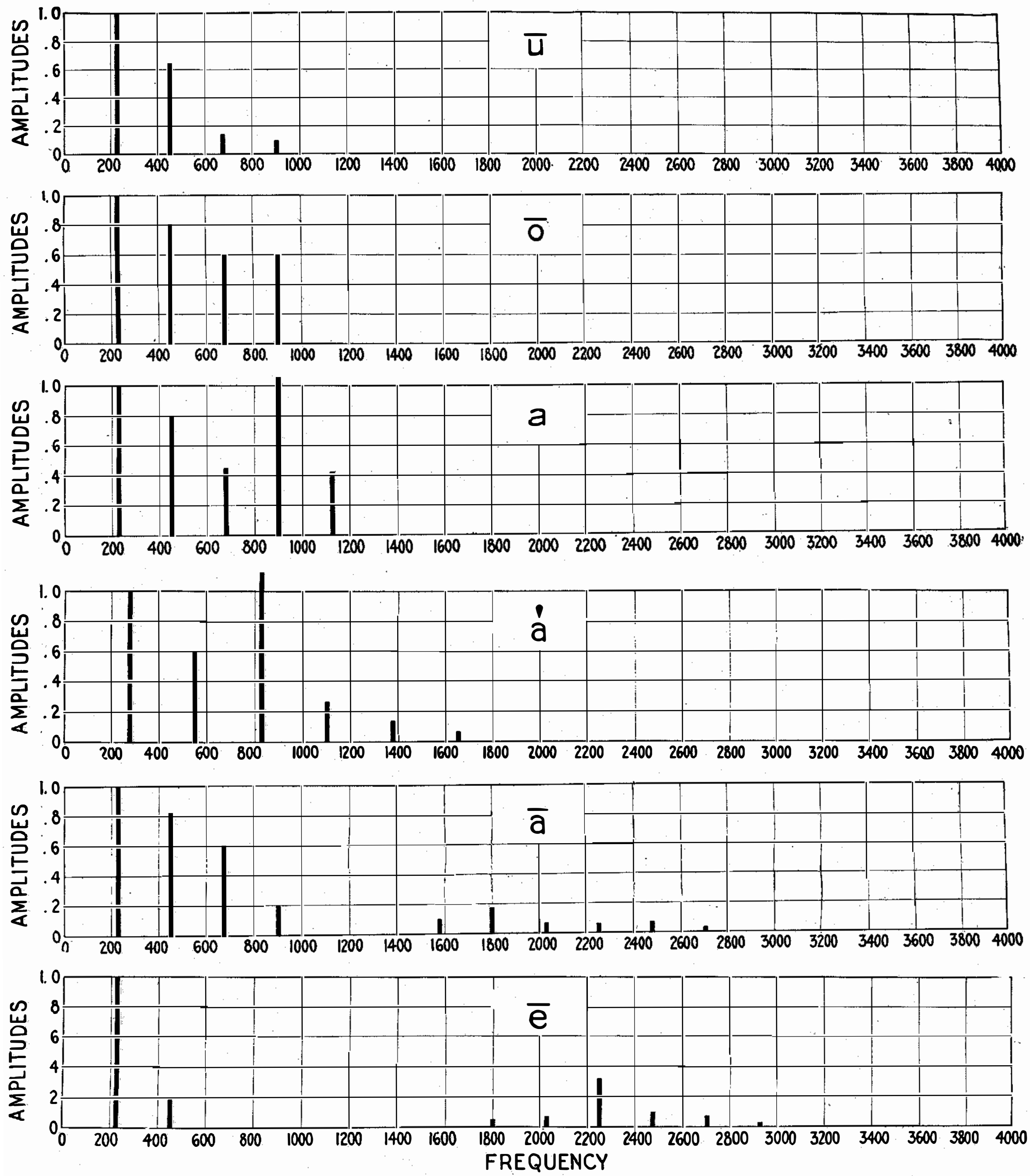
The classified letter sounds are thirty-six in number. The vowels and consonants may be classified phonetically into (a) Pure Vowels, (b) Transitional Vowels, (c) Semi-Vowels, (d) Stop Consonants, and (e) Fricative Consonants. Referring to Figure 1, the triangular diagram at the top of the table represents the first two classes. When a vowel is spoken the vocal cords vibrate in a complicated manner, the characteristics of which are largely determined by the individuality of the speaker. In general, the fundamental or lowest tone of the vibration is rather low in pitch and somewhat lower for men than for women. The mouth and throat cavities, modified by the shape and position of the tongue and lips, act as resonators to reenforce and amplify the relative strength of various harmonics. In this way the shape and position of the mouth and tongue determine largely the particular vowel spoken. The vowel "u" at the upper left of the triangle is formed by rounding the lips, drawing back the tip of the tongue, and raising it at the back in such a way that the throat is almost closed off and the mouth is formed into a single large resonant cavity. Overtones of the cord vibration in the vicinity of about 300 cycles are strongly reenforced. As we come down the left-hand side of the triangle, pronouncing the sounds indicated, the lip opening widens and the jaw is lowered. The tongue is still raised at the back, and we have single resonance until the bottom point of the triangle is reached. In pronouncing the sounds "a" and "á" the lips are wide open. With the former the jaw is dropped, the tongue is only slightly raised at the back, and the most prominent reenforcement is in the neighborhood of 1000 cycles. With the latter the tongue lies flat in the mouth, and the mouth and throat form connected cavities of nearly equal size. There is double resonance, the two reenforced tones lying in the region from about 800 to 1200 cycles. As the vowels on the right-hand side of the triangle are pronounced starting upward from "a," the separation of the lips becomes smaller, the tongue is raised in the center, and then farther forward. These vowels are all characterized by double resonance. With the sound "ē" the lips are drawn to form a wide slit, the tongue is raised in front until its ridge is closely opposite the roof of the front of the mouth. The tongue is drawn forward so that the back of the mouth and the throat form a large resonant chamber. The small tubular space over the tongue at the front leads from the larger space to the exit at the lips. The two frequency regions which are characteristic of the sound "ē" are in the vicinities of 300 and 2500 cycles.

The transition vowels or diphthongs are those formed by passing from one vowel to another. For example, the sound "ī" is pronounced by forming the mouth as if to say "a" and then rapidly passing to the sound "ē." Similarly, the sound designated by the letter "w" is made by forming the mouth as if to say "ū" and then passing suddenly to any of the other pure vowels.

Ordinarily when pronouncing a vowel the glottis opens gently at the beginning of the sound, and the controlled passage of breath produces the sound. If the vocal cords are separated initially in such a way that the glottis is open and the sound is begun by a rather forcible expulsion of breath, the letter "h" is prefixed to the vowel. "l" and "r" partake of some of the characteristics of vowel sounds and are usually classified as semi-vowels.

The stop consonants are those accompanied by the formation of a stop in some part of the mouth. For example, "b," "p" and "m" are all characterized by a stop formed with the two lips. The consonant sound "p" is simply produced by pressing the lips together and then speaking a sound which is begun by having the breath part the lips somewhat forcibly. If the vocal cords are vibrated at the same time the sound "b" is produced. This accompanying vibration of the cords is the characteristic difference between "b" and "p." For the sound "m" the stop is the same and the cords vibrate. The "m" sound is nasal. The lips are pressed together and the breath is released through the nose. The stop at the lips is broken when the sound is terminated or when a succeeding vowel begins. The method of producing the other stop consonants can readily be followed from the table.

The fricative consonants are characterized by the rushing sound of the breath through a characteristic air outlet. We have voiced and unvoiced consonants among the fricative sounds as well as among the stop consonants. For example, the sound "f" is produced by forcing the breath through the air outlet between the upper



ANALYSIS OF VOWEL SOUNDS (SUNG)

Figure 2

teeth and the lower lip. The sound "v" is formed in the same way except with the accompaniment of vocal cord vibrations. The method of producing the other fricative consonants is easily seen by reference to Figure 1.

The speech sounds thus produced in the course of conversation are radiated from the speaker and transmitted through the air by means of pressure waves. These air vibrations are very tiny and exceedingly complicated. In physical analyses of speech it is usually these pressure waves or their duplicates, converted into electrical vibrations, which are studied. Many of the results here described were obtained with a certain type of high-quality electrical reproducing system or circuit as the basis of the experiments. This system consists of a special form of telephone transmitter, a five-stage vacuum-tube amplifier for magnifying the electric speech currents, and, to terminate the circuit, either a group of telephone receivers of special construction or an experimental type of recording apparatus. The design and construction of this experimental system is such that it is probably the most nearly perfect telephonic reproducing apparatus so far built. Its quality is indistinguishable from that of direct air transmission.

In speaking a given letter sound, only the component frequencies of the particular sound (i.e., a sort of "acoustic line spectrum") are being emitted. By impressing a steady sound on the reproducing system mentioned above and by rapidly inserting in succession suitable sharply-resonant filters covering the range of interest, harmonic analyses of the sustained tone may be made. Figure 2 shows the amplitude-frequency characteristics of some of the English vowels obtained in this way. While these results are typical, it is to be noted that they represent the vowel sounds as pronounced by one particular speaker.

But different speech sounds have different components, and moreover the same sound is frequently pronounced at different pitches, since conversational speech has more or less melody to it. In the aggregate speech it may be taken to be represented by a band spectrum. Figure 3 represents the "acoustic spectrum" of English as obtained from a large number of observations with six different speakers.

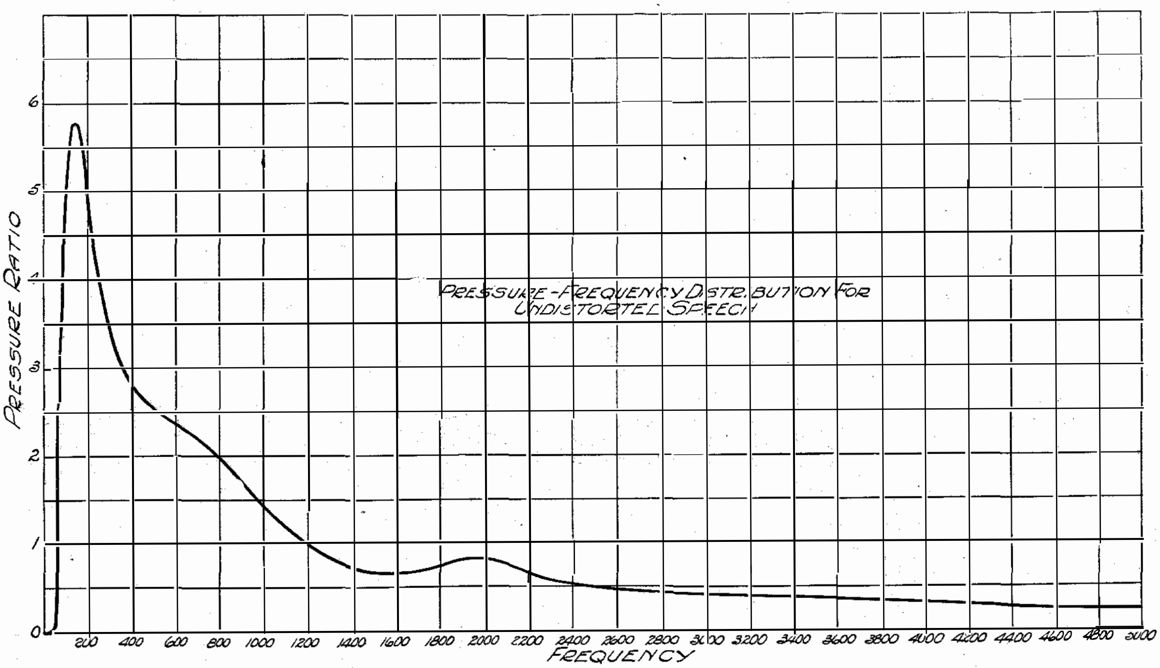


Figure 3

Speech energy extends from a frequency of 60 cycles to above 6000, with a maximum at about 200 cycles. The vowel sounds carry most of the energy of speech and their important frequencies lie below 3000 cycles. The consonants are the characteristic quips and quirks with which the syllables begin and end. They are weak in energy, but very important to good intelligibility. In general, they are rather high in frequency, some of them involving vibrations going up to a frequency of 6000 cycles or even higher. The speech energy output of the normal voice has been found to be at the rate of about 125 ergs per second.

In other terms, simple computation shows that if we could have a million persons talking steadily and convert the energy of the voice vibrations into heat, they would have to talk for an hour and a half to produce enough heat to make a cup of tea. This merely serves to illustrate that in terms of power or energy human speech is exceedingly weak. Furthermore, most of this energy is carried by the vowel sounds. On the other hand, the consonants, as will be shown, are more important to perception and interpretation by the ear, so that energy per se is not so much the primary requirement of speech reproduction, but rather its distribution, and particularly its distribution among the higher frequencies.

The human hearing mechanism is usually considered to have three parts. The outer ear includes the lobe, the ear canal, and the drum. The middle ear is a small hollow space containing the chain of small bones (malleus, incus, and stapes) which comprise the mechanical transmission chain for carrying sound vibrations from the ear drum to a small annular membrane, the fenestra ovalis or oval window. The middle ear also contains the muscles which condition the drum and transmission chain so as to accommodate the mechanism to hearing under the variety of actual conditions.

The inner ear is a spiral space in the bony shell called the cochlea. This space is filled with fluid. It is separated into two compartments by the narrow flexible basilar membrane except at the apex of the cochlea where a tiny passage, the helicotrema, connects the two compartments At the base of the cochlea there is a membraneous diaphragm, commonly called the round window, located on the other side of the basilar membrane from the oval window. Within the spiral casing and terminating on the dividing membrane is the multitude of terminals which connect with the hearing center of the brain through the auditory nerve.

Sound vibrations are transmitted by the stapes through the oval window to the inner ear. At ordinary frequencies vibrations are transmitted through the fluid to a proper distance along the basilar membrane (the appropriate position depending upon the frequency) where they are passed through the membrane and sensed. The excess of vibratory energy transmitted to the second compartment is relieved by the flexibility of the round window. The pitch of a simple tone depends upon the position of maximum response of the basilar membrane—high tones near the base, low tones near the apex of the cochlea. The brain is believed to detect the pitch by its experience in associating tones of different pitches with the stimulation of different nerve groups. When the pitch of the tone is very low, the fluid is moved back and forth around the basilar membrane through the helicotrema. Such impulses follow each other so slowly that the stimulation of the nerve fibers thereby produced is not of the type commonly recognized as a sound sensation. If the pitch of the tone is sufficiently high, the vibratory impedance of the ear mechanism is such that little or no energy is communicated to the inner ear, and in that event also the nerve terminals are unaffected.

The transmission efficiency of the mechanical system linking the ear drum with the basilar membrane is not equal at all frequencies, and its operation varies also with the intensity or loudness of tone. Changes of intensity are probably detected either by change in the amount of agitation of the nerve terminals or by bringing into play wider zones of nerve terminals in the vicinity of the greatest vibration. The marvelous delicacy of the ear mechanism is called to attention when one considers that, in the average case, the basilar membrane by means of which all of these various tones are sensed is only a little over an inch long.

Figure 4 is a plot of auditory sensation for the average human ear. The lower curve shows the sensitiveness of the ear for sounds of different pitches and is called the threshold of hearing. The data was taken by measuring the least sound which could just be heard at each of a number of frequencies. The sensitivity is measured in terms of the minimum audible sound pressure while the frequencies are arranged according to musical intervals (logarithmic scale). The upper curve shows the extreme values of loudness at which the ear begins to experience the sensations of feeling the vibrations. This is the threshold of feeling and may be considered practically as a maximum audibility curve. Sounds much louder than these are painful. The two curves enclose the area of audition. The data have been extrapolated at high and low frequencies to the points of intersection, the extrapolation being guided to a certain extent by other available information. At frequencies in the neighborhood of sixty cycles a high intensity is felt as a sort of flutter. As the frequency is lowered still farther to the point where the hearing and feeling lines appear to intersect, it is difficult to distinguish between the two sensations. For frequencies lower than this it is easier to feel than to hear the air vibration. A similar intersection of the two curves occurs at a very high frequency. This appears to give a logical basis for defining the frequency limits of hearing, and as seen from the plot they are about

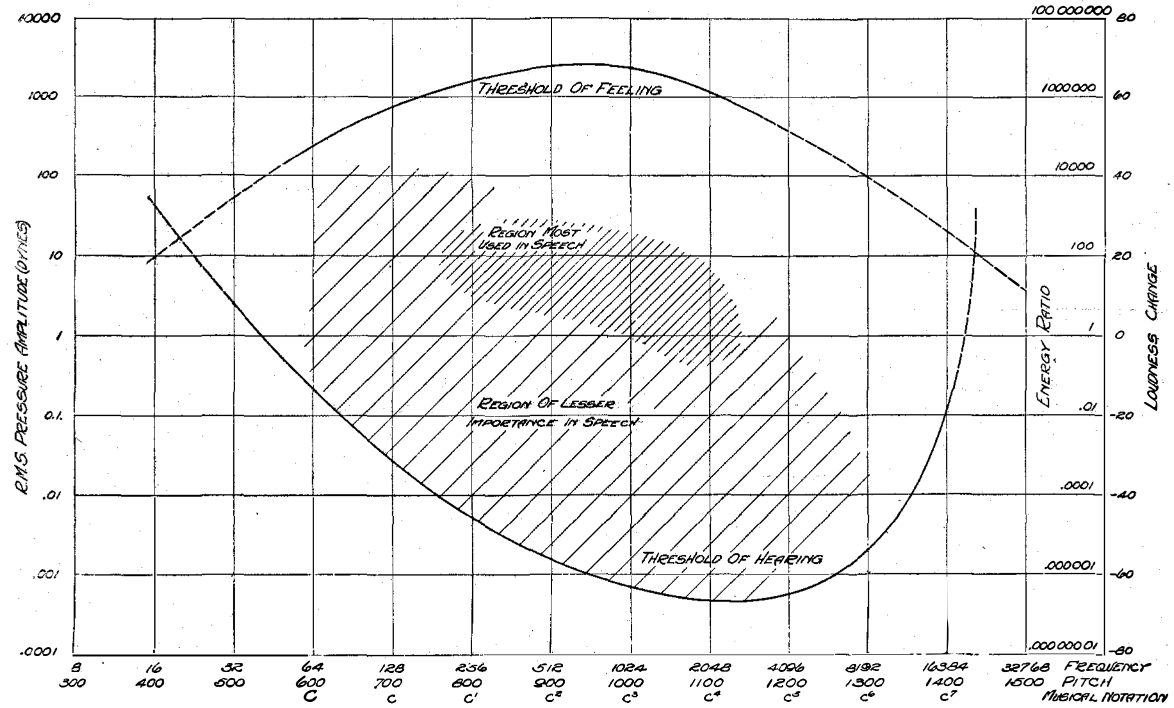


Figure 4

20 and 20,000 cycles respectively for persons of average hearing. At the lower and upper limits of audition it takes about a hundred million times as much energy to enable one to hear as it does in the range of 1000 to 5000 cycles where the ear is most sensitive. At all frequencies the energy required is small, and in the most favorable region the minimum audible tone corresponds to a pressure change per square centimeter of about .001 of a dyne. This pressure is roughly equivalent to the weight of a section of a human hair about one thousandth of an inch long (about one-third as long as its diameter).

In the portion of the audible region most commonly used, it is found that the smallest change in the intensity of a tone which is just discernible, is equal to about one-tenth of its original value. In other words, in general the law connecting loudness discrimination with the energy of the tone is a simple logarithmic one. It has been proposed that change in loudness sensation be measured in units such that a loudness change is equal to ten times the common logarithm of the ratio of the energies.

It has been found that the law of pitch sensibility is approximately logarithmic also. The fractional change in frequency which is just perceptible is equal to about three-thousandths over the greater part of the ordinary musical range. The ear perceives octaves as somewhat similar sounds. With these and other facts of hearing in mind, it has been proposed to measure pitch sensation on a scale such that the pitch of a tone will be given by one hundred times the logarithm to the base two of the pitch number or frequency. These sensation scales of loudness and pitch are given on Figure 4 in addition to the physical scales of energy and frequency. From the observations made on intensity and pitch discrimination, it is possible to show that approximately three hundred thousand different pure tones are separately distinguishable by the average ear. The number of complex sounds which can be sensed is even much greater.

The non-linearity of operation of the ear gives rise to a number of interesting hearing phenomena. When a simple tone is made very intense the vibratory efficiency of the middle ear and cochlea are no longer constant. This gives rise to harmonics which cause the basilar membrane to vibrate in other zones than that characteristic of the fundamental. If a second intense tone of another pitch is now impressed, its harmonics are also introduced. Under some conditions combination tones appear having frequencies which are the sums or differences of the fundamentals or harmonics. Some of the combination tones may take the form of beats. Such harmonics, combination tones, and beats are purely subjective effects brought in by the departure from linearity of the vibratory mechanism of the internal ear.

The masking of one tone by another is a second effect of interest. An intense low tone is observed to mask or obscure weaker, high tones; but high tones, even though intense, have scarcely any masking effect on lower ones. The explanation offered for this is that the intense low tone, with its subjective harmonics, sets up vibrations in the basilar membrane which extend along the membrane to a considerable distance from the base of the cochlea so that vibrations of higher frequencies which might otherwise obtain in the adjacent region, are interfered with. With the opposite state of affairs, the high-pitched vibrations extend only a short distance from the base, and more remote portions of the membrane are free to sense tones of lower pitch.

It will readily be apprehended that with complex tones complicated effects may be obtained. When such a tone is made very loud, as by amplification, its tone quality may be greatly altered even though its composition is in no-wise changed. In general its low frequency components will appear more prominent and its higher frequencies diminished.

Referring again to Figure 4, the area of sensation most used in conversation is represented approximately by the shaded area of the figure. The more intense vowel-like sounds account for the upper part of the shaded region, while the weaker consonants account for the most part for the shaded regions of lower intensity and higher frequency. It is evident that the processes of evolution have worked out in such a way that conversation usually employs the central part of the area of audition. For clear understanding the weaker consonant sounds must not fall below the threshold of hearing nor must the loudest speech sounds rise to such intensity that the threshold of feeling is reached or non-linear effects introduced.

Defective hearing is lacking more or less in range of sensation (that is either frequency or intensity), quality of sensation in various parts of the sensation area, or in the binaural sense or the ability to locate the direction from which a sound is received. While space will not permit a discussion of abnormal hearing, Figure 5 is presented to illustrate the way in which defective range of sensation may be measured and compared with normal conditions. The area of audition plot is again reproduced together with hearing-threshold curves, or audiograms, for a person whose hearing is subnormal due to catarrhal deafness. The areas between these threshold-of-hearing curves and the threshold of feeling are the diminished areas of sensation for the respective ears. The scales used in plotting the area of audition are such that the area of any part of the diagram represents approximately the number of simple tones which can be distinguished in that region. Hence, the proportional part of the whole area in which sensation can still be perceived may be taken as a measure of deafness. It is apparent that the subject retains about fifty per cent of the normal range in this case. He hears and interprets conversation with some difficulty. A suitable deaf set amplifying the speech region to the position indicated by the dashed lines would be of some assistance. Certain of the weaker consonant sounds would frequently be low enough in intensity to drop below the range of his hearing even with this aid, however, If too great amplification were provided, the energy of some of the vowel sounds would give rise to subjective distortion and might even produce painful sensations. It is of interest to note that an unusual degree of non-linearity is characteristic of some types of defective hearing. It is evident that in prescribing aids for the deaf, great care must be exercised in order that there may be no danger of injury and in order that the best results may be obtained.

For the study of the interpretation of speech it is necessary to be able to adjust at will the loudness of the speech sounds and to introduce determinable amounts of distortion. With acoustic apparatus this is very difficult and consequently for many years meager results were obtained. The recent development of the vacuum tube and the electric-wave filter make it possible to produce the equivalent of the desired changes in the high quality reproducing system mentioned above. By means of distortionless controls operating on the amplifier the loudness of the reproduced speech is varied through a very wide range. By inserting electric-wave filters in the circuit the speech waves can be distorted in known ways. For example a low pass filter suppressing frequencies above 1000 cycles is connected in circuit and articulation tests made to find the intelligibility carried by frequencies between 0 and 1000 cycles. For experimental purposes it is practicable to construct such filters in which the suppressed frequencies are diminished to one-millionth or less of the values which would otherwise obtain, while the passed frequencies are scarcely affected. Similarly high-pass filters can be made which suppress all frequencies up to a certain marginal region and pass those above it. Such filter structures are made by the proper combination of suitable inductance coils and condensers.

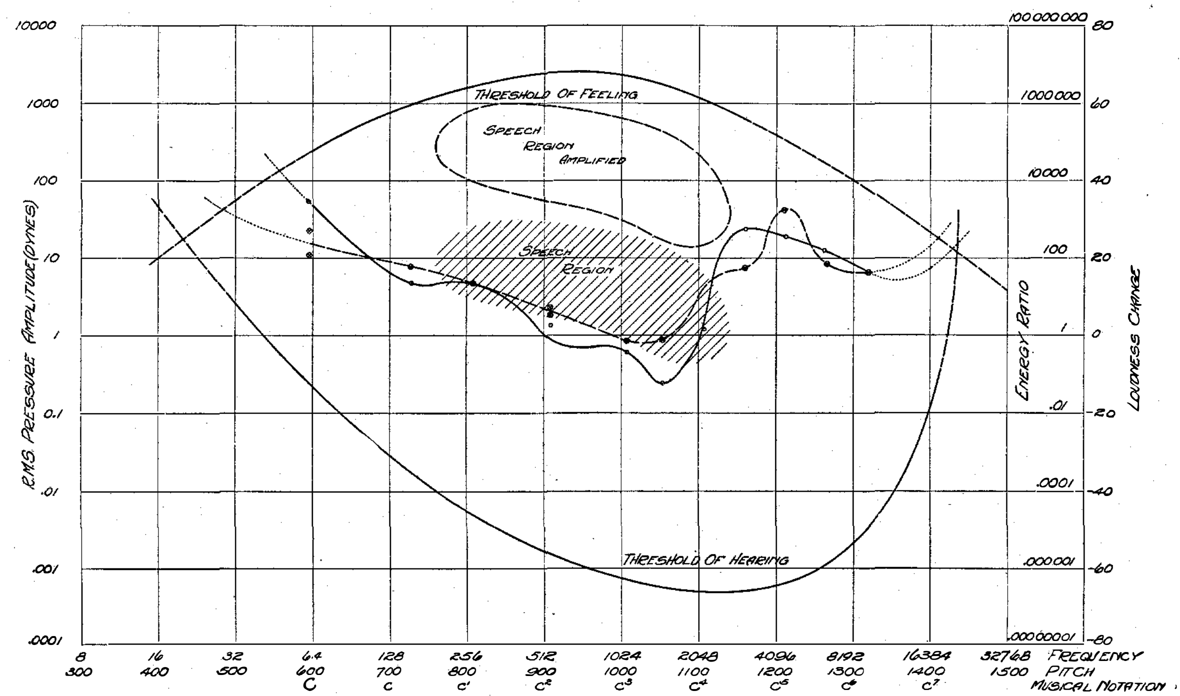


Figure 5

Studies of interpretation further require an experimental method for measuring the ability of the ear to understand transmitted speech sounds with different conditions of loudness and distortion. The method developed consists in pronouncing detached speech sounds into the transmitting end of the experimental system and in having observers at the receiving end write the sounds which they hear. Comparison of the observed sounds with those called shows the number and kind of errors made. The per cent of the total sounds spoken which are correctly received is called the articulation of the system. For these tests simple syllables are used constructed in a systematic manner from the 36 fundamental speech sounds and arranged in lists of 50 syllables each. A carefully worked out technique is observed in the testing.

Articulation tests have been made upon the high quality experimental system without distortion, but with controls adjusted to give various intensities of output from the threshold of audibility to values considerably above the level of ordinary conversation. The results obtained are shown in Figure 6. The abscissas of the curve represent loudness and are expressed as the ratios by which the speech energy has been decreased from the initial intensity at exit from the mouth. When the volume is reduced to about one ten-billionth of the initial speech intensity, the articulation becomes zero. This point corresponds to the value at which speech becomes inaudible. At about one thousandth of the initial speech intensity, the articulation becomes a maximum. With louder speech than this perception is less accurate, probably due to overloading of the ear mechanism and subjective distortion. These results were obtained in a perfectly quiet room. When the observer is submerged in an atmosphere of noise the speech must be louder in order to get the best hearing conditions.

The articulation data have been further analyzed in such a way as to show the errors made at various intensities for each of the fundamental sounds. The results for some typical sounds are shown in Figure 7.

It is observed that in general diphthongs and vowels are more easily heard than consonants, and that of the latter the stop consonants are heard with fewer mistakes than are the fricative ones. If all the sounds are listed in order of average articulation the top quarter will contain no consonants and the lower half no vowels. When speech becomes weak, the errors of the consonants increase greatly, their articulation values falling off at higher intensities than is the case with the vowels.

There are some exceptions to these general statements. At moderate volume the short vowel "e" is near the bottom of the list, but at very weak volume 22 sounds are harder to perceive. "l" "r" and "ng" are all more readily heard than "e" at moderate volume, but when very weak they fall below it. "l", which ranks with the diphthong "ī", as one of the easiest sounds at moderate volume, is mistaken about two times out of three when very weak.

The diphthongs "ī", "ou", and the long vowels "ó", "ō", "ā", all have average articulations better than 95 and even when very weak have values of 84 or better. On the whole the sounds "th", "f",

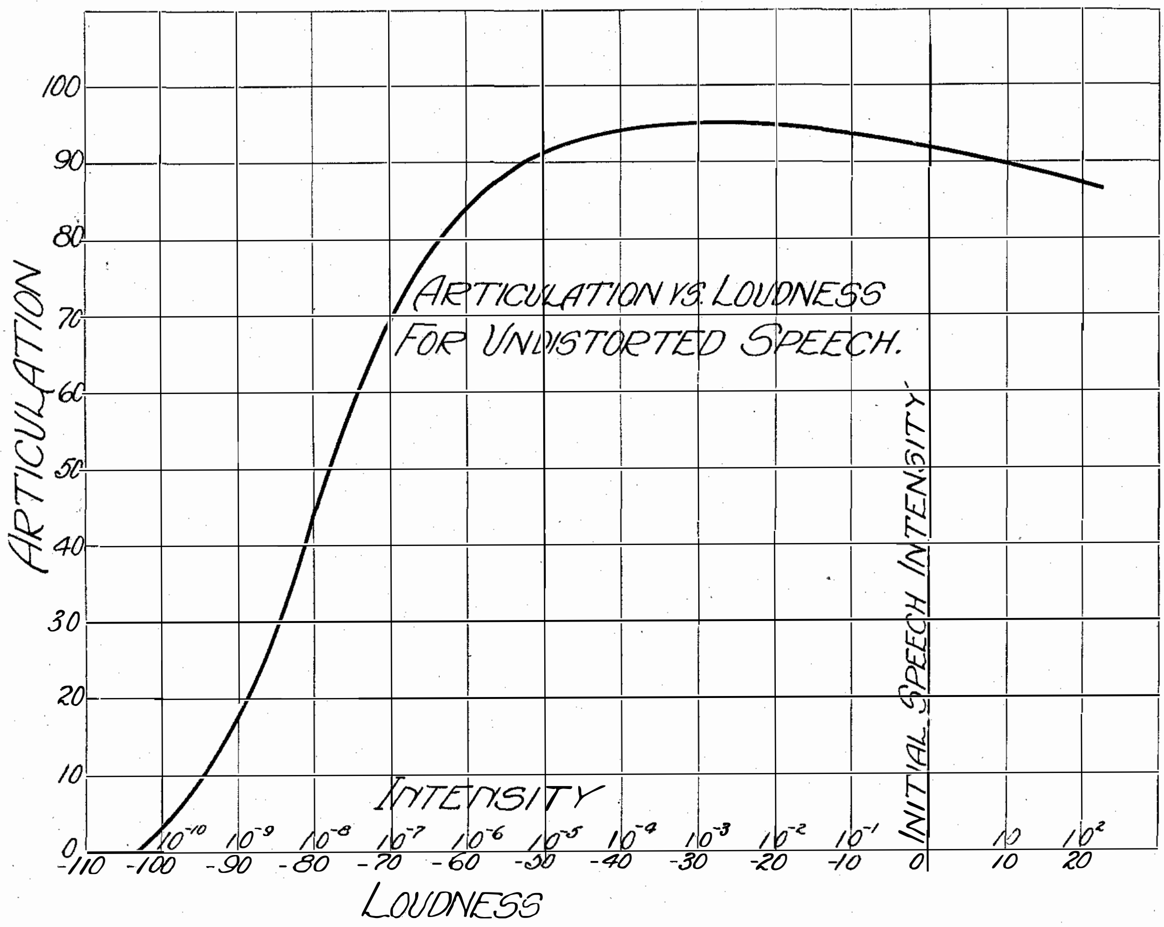


Figure 6

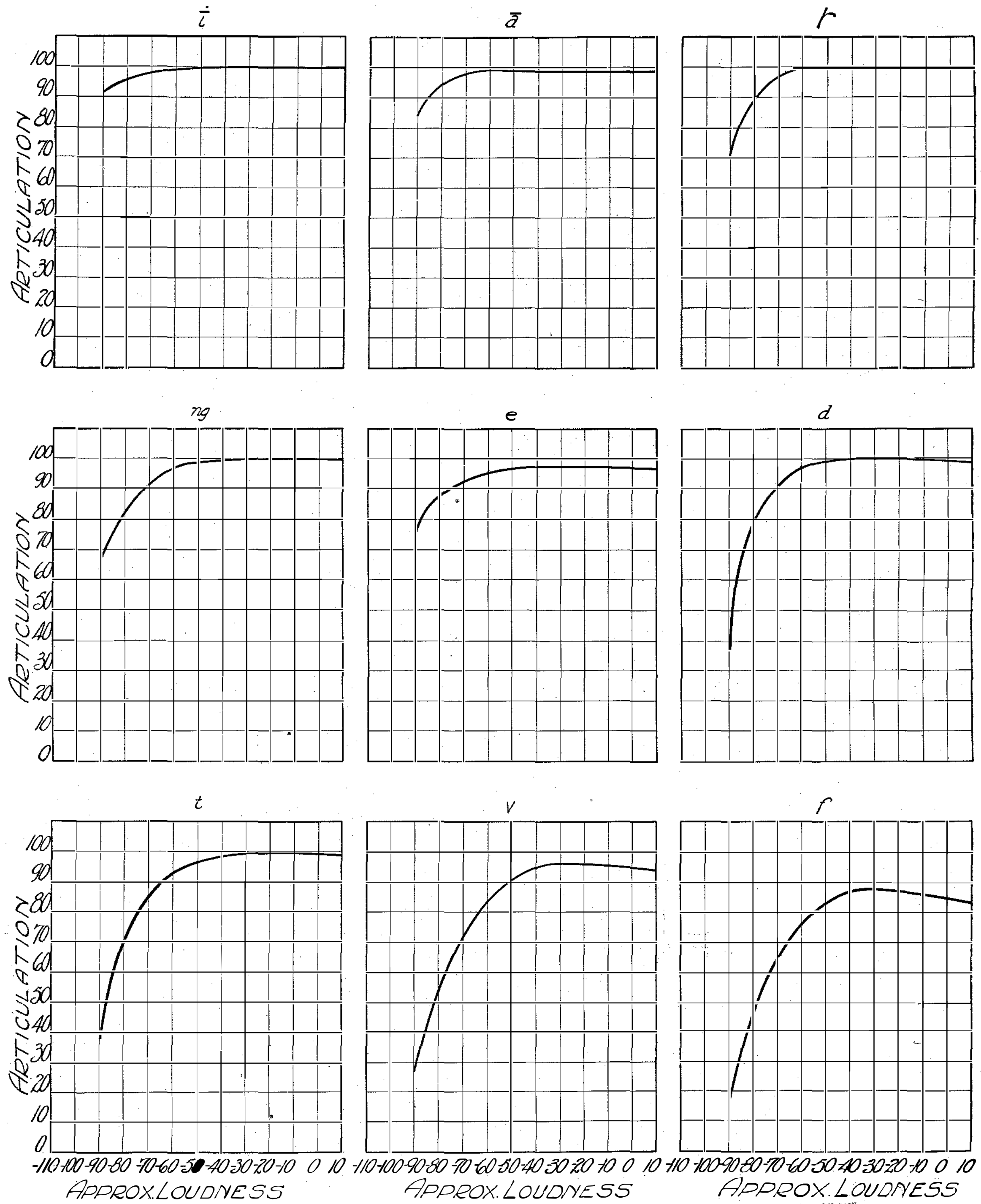


Figure 7

"s", and "v" are hardest to hear correctly, and they account for more than half of all the errors of interpretation. In general, it is observed that the volume at which errors begin to be large is different for different sounds and is usually higher for the consonants than for the vowels. Within the precision of the data, the intersections on the axis of abscissas all correspond with the threshold of hearing.

The effect of frequency distortion has been investigated by inserting several systems of electric wave filters in the high-quality experimental circuit. Articulation results with low-pass and high-pass filters are shown in Figure 8. The ordinates show the per cent of syllables called which were correctly recorded at the receiving end. The abscissas represent the marginal or cut-off frequency of the filter. Looking at the curve for the low-pass filter, marked Articulation L, the point (1000,40) indicates that an articulation of forty per cent is obtained when the system transmits only frequencies up to 1000 cycles. Looking at the curve for the high-pass filters, marked Articulation H, the point (1000,86) indicates an articulation of eighty-six per cent for a system transmitting only frequencies above 1000 cycles. The dotted curves show the per cent of the total energy in speech transmitted through filters of the two types having cut-off frequencies corresponding to the abscissas. Sixty per cent is lost if all the energy has no greater effect than the suppression of the frequencies above 3000 cycles. This is quite contrary to the popular notion of the characteristics of speech. The mean frequency from the standpoint of articulation is about 1550 cycles. An articulation of sixty-five per cent is obtained when either the frequencies below or those above that point are used. The speech quality sounds very different in the two cases, however, in the one being low and dull, and in the other high and shrill.

It should be borne in mind that naturalness of reproduction, as well as articulation, is an important element of understandable and satisfactory spoken communication. As has been pointed out above, although the fundamental cord tones and harmonics lying below 500 cycles carry most of the speech energy, they contribute little to the articulation. It has been observed

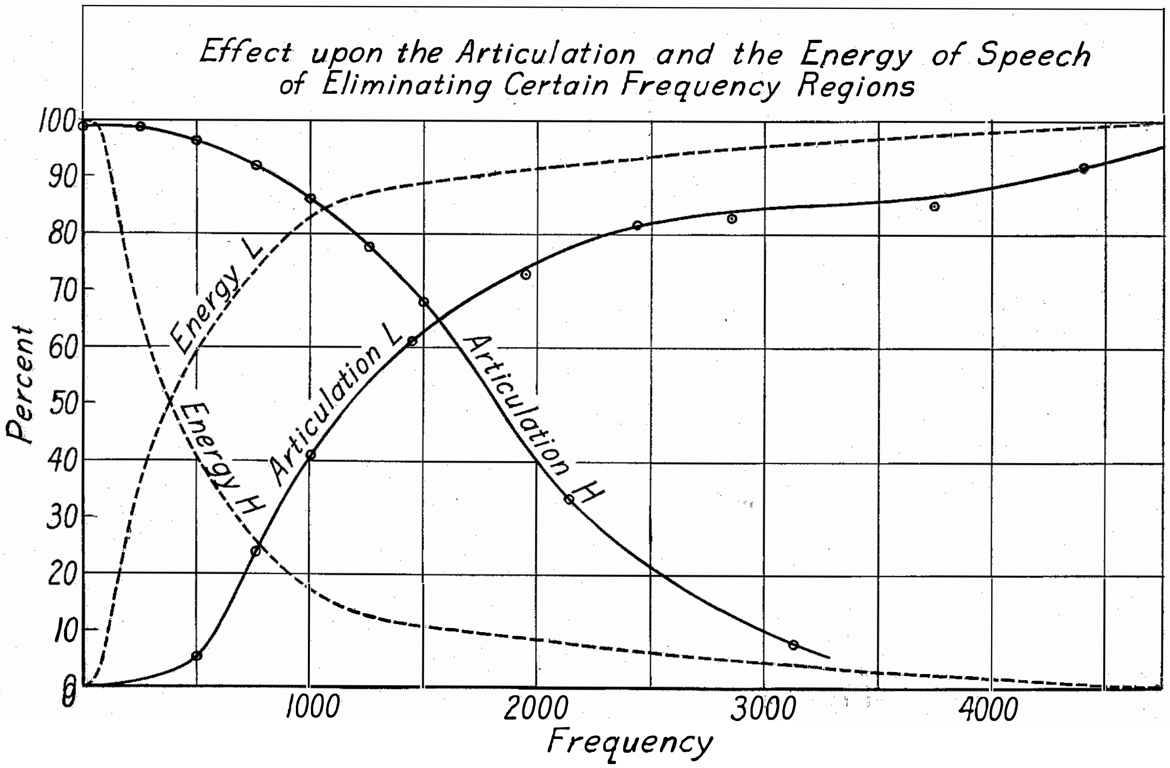


Figure 8

below 500 cycles is eliminated, but only two per cent of the articulation. The suppression of the frequencies above 1500 cycles reduces the articulation by thirty-five per cent but only ten per cent of the energy lies in this region. The suppression of all frequencies below 1000 cycles that naturalness of reproduction is greatly affected depending upon whether or not these low frequency tones are preserved. While it might be concluded from the articulation data then, that frequencies in the lower part of the speech range are unimportant, a fuller consideration justly attributes an added measure of importance on account of naturalness. The naturalness of speech quality is a characteristic calling for considerable further investigation.

The curves of Figure 9 show the articulation of some typical speech sounds when the frequency regions below or above the given point are suppressed. The ordinate gives the number of times the sound was correctly observed per 100 times called; the abscissa, the frequency of cut-off. In each figure the effect of suppressing the frequencies below the cut-off is shown by the curve at the left, the effect of suppressing those above it by the one at the right. The diphthong "ī," the long vowel "ē," and the semi-vowel "l" are each perceived with an error less than three per cent when either half of the frequency range is used. The intersections of the two curves, the cut-off frequency where the articulation is the same with either low-pass or high-pass filters, are at different points in each of the three cases, however.

In the cases of the short vowels "u", "o", and "e", the frequencies below 1000 cycles are important to good articulation, but those above 2000 may be suppressed with little effect.

In the cases of the fricatives "s", "z", and "th," quite different effects are observed than with the former two classes. Some of the peculiar results shown have not yet been explained. Even if all frequencies up to 5000 cycles are correctly transmitted, these sounds are noticeably impaired by the suppression of those above. The lower frequencies up to 1500 cycles contribute practically nothing to the articulation of "s" and "z". It has been observed, in the case of a system which suppresses all frequencies above 2500 cycles, that about 82 per cent of the syllables were heard correctly in an articulation test, and that the errors were made up principally of failures in the three sounds "s", "z", and "th".

In conclusion then, we have seen that the ordinary ear is an exquisitely developed organ for sensing minute and rapidly repeated variations in air pressure. It can perceive sound waves ranging in pressure amplitude from less

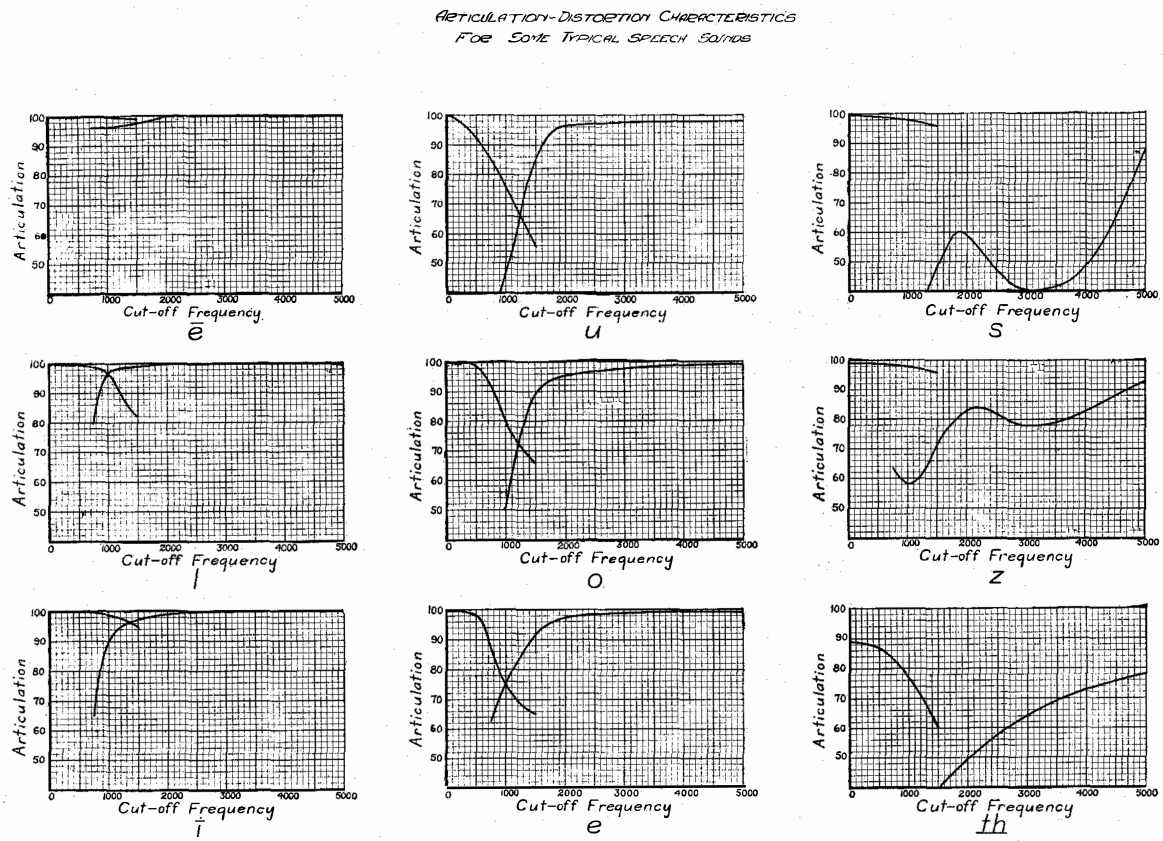


Figure 9

than .001 dyne to over 1000 dynes, and in frequency of vibration from about 20 cycles per second to about 20,000—a range of about ten octaves. Human speech employs frequencies from a little below 100 cycles per second to above 6000 cycles—a range of about six octaves. The intensities and frequencies used most in conversation are those located in the central part of the area of audition. The energy of speech is carried largely by frequencies below 1000, but the characteristics which make it intelligible, largely by frequencies above 1000. Under quiet conditions good understanding is possible with undistorted speech having an intensity anywhere from one hundred times greater, to a million times less than that at exit from the mouth. On the whole, the sounds "th", "f", "s" and "v" are hardest to hear correctly and they account for over half the mistakes made in interpretation. Failure to perceive them correctly is principally due to their very weak energy although it is also to be noted that they have important components of very high frequency.

These data are of fundamental importance in the art of electrical communication. But they have also a broader interest and utility. The information gleaned by physicists in the study of speech and hearing increases the understanding of phoneticians and physiologists. It will aid public speakers, linguists, and physicians, and help to lighten the burdens of the deaf and dumb. Investigators who engage in the field of human acoustics have many interesting physical problems to solve. Furthermore study of these senses, dealing as it does with two of the primary tools of the human race, is work of extraordinary appeal holding forth promises of direct service to mankind.

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Use of Labor-Saving Apparatus in Outside Plant Construction Work

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Introduction

IN the February issue of ELECTRICAL COMMUNICATION was discussed the adaptation of transportation equipment to telephone construction and maintenance work. Closely associated with the operation of such equipment is the problem of utilizing various labor-saving machinery which in many cases has been so designed as to form an integral part of the transportation unit.

It is the purpose of this article to describe some of the more important developments along this line such, for example, as the application of different types of derricks, trailers for various kinds of work, earth boring machines, numerous applications of air compressors and compressed air tools, etc., and in some instances to contrast the latest types of equipment with former manual methods of carrying out similar operations.

Pole Derricks

There are erected in the Bell System each year in the neighborhood of 600,000 new poles. In addition, the maintenance of the existing plant of over 14,000,000 poles involves the moving, removing, resetting and straightening of large numbers of poles annually. This immense task emphasizes the importance of devising means for offsetting, in so far as is practicable, the old manual methods of handling these poles on the job and from point to point in the field as occasion demands.

In 1914 there was developed and put into use a pole derrick of the tripod type which was mounted upon a 5-ton truck from which the derrick received the necessary power for operation. As the use of this derrick, which weighed something over ½ a ton, was extended it became very apparent that while the fundamentals of the design and operation were reasonably well adapted to the average construction job, the weight and bulk of the apparatus introduced a very real factor with regard to the available truck capacity. The derrick members, being large and heavy, were difficult for the men to handle and there was not in all cases the desired amount of flexibility to meet the varied and often difficult requirements. This derrick, however, clearly demonstrated the inestimable value of apparatus capable of doing in a few minutes the work of a large gang of men, ordinarily requiring many times as long to complete.

An active period of development and experimental field work soon followed the advent of this labor-saving device which has resulted in making available a light type of high grade steel tube derrick.

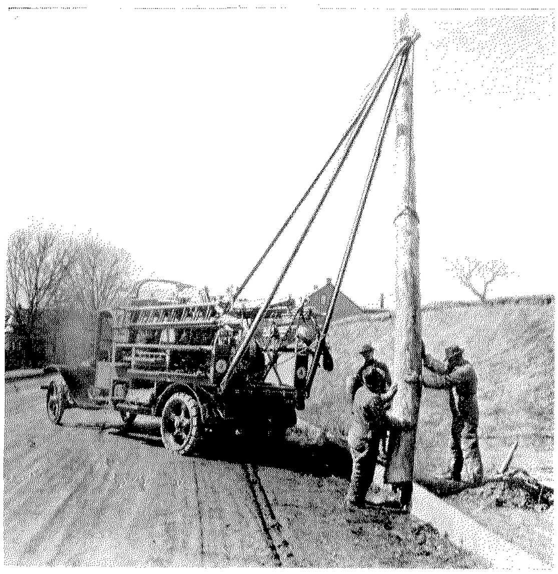

Figure 1—Erecting Pole, all Derrick Members Mounted on Truck

Figures 1 and 2 show a pole derrick of the latest type mounted on a 2½ ton truck. Figure 1 illustrates the method of erecting a pole where the truck can be maneuvered into a position in close proximity to the proposed location of the pole. Figure 2, on the other hand, shows the possibility of handling a pole at a considerable distance from the location of the truck, which for any reason may be more practicable or desirable.

These illustrations show the derrick in each of the two possible operating positions; in the first instance supported entirely upon the truck, and in the second, supported from the ground by one of the three pipe members. The derricks of this type are constructed of high grade steel tubing having a strength at the yield point of approximately 70,000 pounds per square inch.

Naturally, the greatest economies may be made in the application of this apparatus where the poles to be handled constitute a consecutive line, the holes for which have been dug in advance. However, because of the short time required for assembling and taking down the derrick, it is generally economical to use if for placing only one or two poles at a location. As indicative of the possibilities with regard to rapidity of operation, it may be of interest to note that in erecting a number of 30 to 35 foot poles under average conditions in a line for which the holes had previously been prepared, a gang of three men have averaged approximately two minutes per pole erected but not tamped.

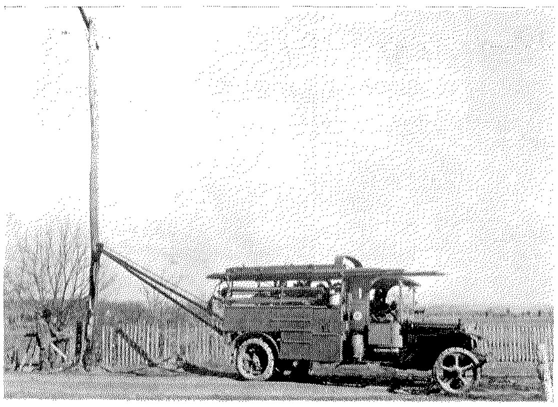

Figure 2—Erecting Pole at Distance from Truck, One Derrick Member on Ground

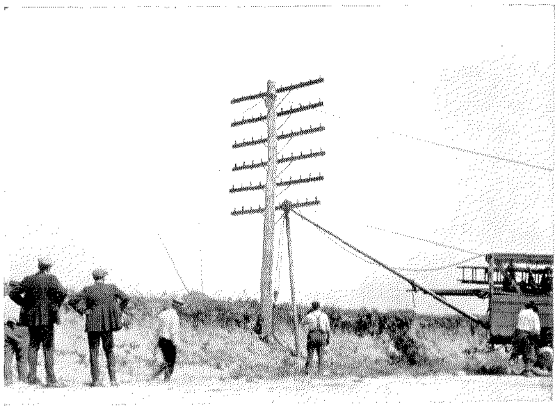

Figure 3—Derrick in Position to Pull Pole Out of Ground

In order that country-wide conditions may be satisfactorily met, the present type of derrick has been made available in two general types which are known as the "middle" and "corner" types for use, as the names imply, from the rear middle or the corner of the truck. Each of these types are further available in light and heavy weights, depending upon the lengths and the kinds of poles, cedar or chestnut or other kinds of similar weights, that are generally used in any particular part of the country.

As contrasted with the early type of derrick, the present light middle type weighs from 370 to 520 pounds, depending upon the size used, and is capable of readily and safely handling any load within the limits of the winch rope capacity which leaves a satisfactory margin when doing practically any work for which the derrick has a place in telephone construction. Each of the four classes of derricks above mentioned is designed with a view to making its operation as rapid as is consistent with safety. The chauffeurs and one man can remove the derrick members from the carrying racks provided on the truck, assemble them and erect the derrick ready for work in from three to four minutes. The disassembling of the derrick requires about the same length of time.

The use of the derrick has thus far been described as applied to the economical erection of poles. There are, as a matter of fact, many other important uses for which the winch-operated truck is well adapted, a few of which are enumerated below.

Road and highway changes and improvements throughout the country make it necessary for the telephone companies to annually move thousands of poles to the new highway limits or curb lines. In many instances these pole lines carry heavy loads of wire or cable or both. With the pole derrick many of these moves can readily be accomplished without in any way disturbing the wire or cable loads. The derrick pulls the pole out of the ground and with the aid of the truck the pole with its load intact is moved to the new location where it is lowered into the hole prepared without even untying a wire or loosening a cable clamp. It will also be readily appreciated that the rehandling of cable and particularly the untying of open wires is not only an expensive operation in point of first cost, but that each such operation is distinctly detrimental to the plant, shortening its life and greatly increasing maintenance expenses. It will be seen, therefore, that the use of the derrick where practicable in connection with the moving of existing lines will largely eliminate the undesirable and costly procedure which is involved in the manual handling of the poles.

As an example of one of the many uses to which the pole derrick can very satisfactorily be put, Figures 3 and 4 illustrate the initial and final steps in moving back a pole in a 6-arm lead of wires and lifting it up an embankment to its new location in connection with highway widening. This particular line is about 60 miles long and the distance the poles were moved varied between 6 and 125 feet. It is reported that the move of this entire lead which averaged about 4 arms was completed without untying a single wire, without cutting any slack and with practically no trouble on the circuits. It is needless to say that the saving involved by being able to move this line rather than rebuild at the new location was an item of considerable importance.

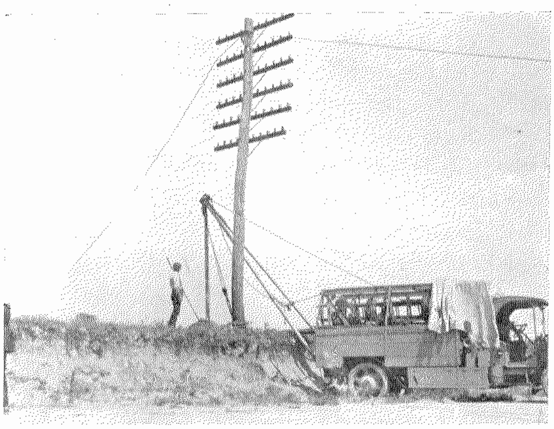

Figure 4—In Position to Shift Pole to New Location. Pole Has Been Moved Over Bank with Wires Intact

In Figure 4 the pole is shown after having been pulled out of the ground and placed on top of the embankment. The derrick is ready to shift and slide the pole back to the new hole. Two men and the chauffeur pulled and completed the moving of this pole with its load of six arms of wires in twenty-five minutes.

As a further example of the usefulness of the derrick in pole work, Figure 5 shows a job where the pole derrick was operated under rather unusual conditions to erect a pole at the side of the road where the pole hole was dug under water and the pole erected in barrels. It would be difficult to pike a pole into such a hole because there is nothing against which to rest the butt while raising it.

Figure 5—Derrick Operating Under Difficult Conditions

Another important function of the derrick is that in connection with the resetting of poles or the removal of abandoned poles when it is necessary to remove the butts. The slow and laborious process of pulling the pole out of the ground with a jack or other equipment is practically eliminated as the derrick, properly handled, is capable of doing the greater part of this work in much less time, more economically and with greater safety to the men.

In addition, it might be pointed out that the derrick equipped truck is also becoming more and more indispensable in connection with the handling or moving of any heavy loads in the storage yards, in unloading or in moving stock supplies of poles under adverse conditions and many other uses.

In contrast with the mechanical methods of erecting and handling poles as previously shown, Figure 6 shows the old manual method of erecting a large pole. Not only is the number of men required large, but the observance of most rigid precautions does not entirely preclude the possibility of hazard to the men when handling the heavier poles. Further, the pole locations are not always such that a considerable number of men with pikes can properly distribute themselves about the pole so as to complete the raising and lowering operations in a reasonably safe and efficient manner.

Figure 6—Erecting Pole by Manual Methods. Contrast with Previous Operations

Earth Boring Machines

One of the slowest and most difficult physical tasks connected with outside construction work is that of digging pole holes. It is estimated that upwards of 1,000,000 holes must be dug annually to accommodate the poles erected in new locations, and those replaced, moved and reset in the Bell System. Under soil conditions reasonably free from obstructions a man can generally average about three holes per day with perhaps five or six as a maximum under ideal soil conditions, while in more difficult digging one or possibly two holes may represent a good average day's work. It probably requires somewhere in the neighborhood of 3,500,000 man-hours per year simply to dig pole holes.

For a number of years the availability of a practical pole hole digger has been the objective of telephone linemen. Development work has progressed rapidly during recent years and the high point of perfection which has been reached in automobile truck design and performance has greatly simplified the adaptation and increased the practicability of the boring apparatus. It is of interest to note in this connection that the solution of the problem comes at a time when there is a pronounced shortage of common labor.

The construction in 1914 of that portion of the transcontinental line extending across Nevada, marks the first really economical application of a machine to bore pole holes. In about 1917 the need for labor relief led to renewed activity in connection with adapting the fundamental principles of the original boring apparatus to machines sufficiently flexible to meet the general and rather exacting requirements of telephone work.

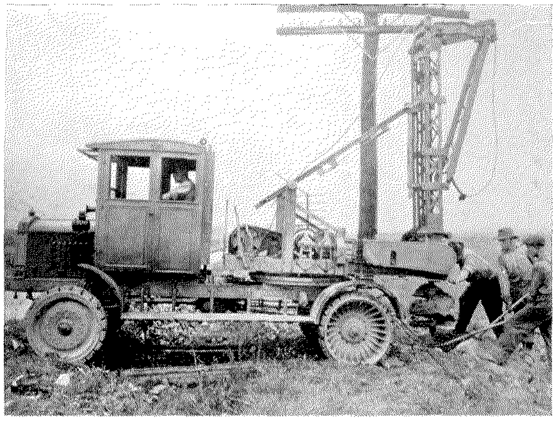

Figure 7—Boring Hole for "H" Fixture

Figure 7 shows one of the latest developments in earth boring machines, which is cleancut and rugged. This machine is mounted upon a 4-wheel drive truck and is otherwise specially equipped which enables it to reach practically any location where it is necessary to bore holes for the erection of poles. As a matter of fact it has been demonstrated that these machines are able to reach approximately 95% of the pole locations. Further, the machine being equipped with a pole raising derrick makes possible the digging of the hole and the setting of the pole with but one setting of the truck.

With the boring machine from 30 to 80 poles per day can be set in their holes by a force of three men. This, of course, does not include straightening the poles and backfilling the holes.

To do this amount of work with manual labor only would ordinarily require from 15 to 50 men. It is of particular interest to note that the more difficult the digging, exclusive of rock, of course, the greater the saving by using the machine. It might be mentioned that one of the most important features of the boring machine is its ability to bore holes through frost thus enabling a more uniform apportionment of pole work over the entire year. This feature is also of particular value in connection with the restoration of service subsequent to sleet storm breaks in midwinter at which time hand digging is in many cases a practical impossibility.

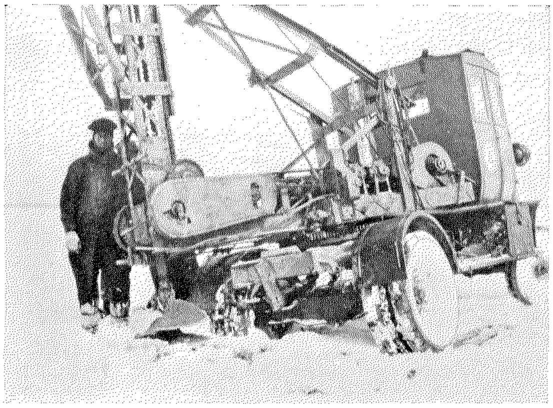

Figure 8—Machine Extricating Itself from Hole

Figure 8 illustrates the ability of this 4-wheel drive outfit to negotiate difficult ground conditions. In this instance one rear wheel has dropped into a hole while traveling over a plowed field covered with snow. It required only a few minutes to lift the wheel by moving the turn table so that the auger was just behind the buried wheel, then raising that corner of the truck by forcing down the auger with power from the engine, sliding a skid board under the wheel thus raised, lowering the wheel to this board and driving away.

Cable Reel Trailers

To meet the need for a device suitable for trailing a single reel of cable and also for use as a reel "set-up" preparatory to a "pull" of either underground or aerial cable, a type of cable reel trailer has been developed as illustrated in Figures 9 and 10.

A number of trailers of this type have been in service for some length of time and their use has brought out many advantages, some of the more important of which are:

Figure 9—Truck Being Used to Load Reel of Cable on Trailers

A reel of cable can be loaded on and unloaded from the trailer in less time and with less effort than when a reel is carried in the body of the truck. In this connection, it might be pointed out that an important safety feature is involved in that the hazards to the men in loading and unloading heavy reels of cable are practically eliminated. Of course, even where reels of cable are carried in the truck the use of the winch and spindle as previously discussed in the February issue eliminates the hazard that was present in the old method of loading and unloading, involving the use of skids.

Fewer men are required for loading, unloading and "setting-up." For example, two men with a chauffeur and truck (not

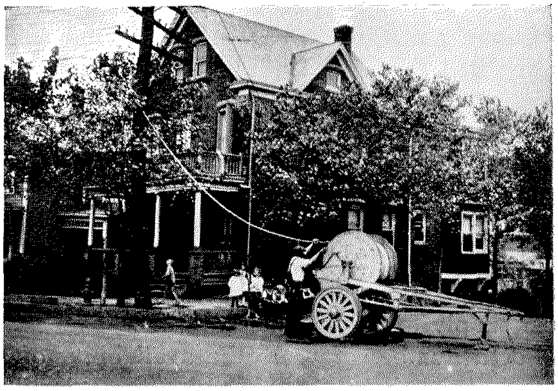

Figure 10—Cable Being Pulled into Rings from Reel "Set-up" on Trailer

necessarily equipped with a winch) can satisfactorily handle a 3-ton reel of cable with the trailer, where ground conditions are such that they can maneuver the reel on the ground.

Where a single reel of cable is to be used for one "pull" or for a number of short "pulls," the trailer is used to haul the reel to the job and to "set up" the reel for each "pull." The reel may be trailed, in addition to carrying materials, tools, etc., in the body of the truck, thus making it unnecessary to unload or disarrange the equipment regularly carried on the truck.

When delivering a number of reels, one reel may be trailed in addition to carrying one or more on the body of the truck, thus materially increasing the hauling capacity of the truck, with a proportionate reduction in delivery costs.

As the photographs indicate, these trailers are equipped with springs and rubber tires which afford material protection to the cable while in transit.

Pole Trailers

For the transportation of poles under ordinary conditions, the use of a two-wheel trailer with the poles balanced on the trailer and towed behind the truck is ordinarily the most satisfactory method. Figure 11 shows such a trailer loaded and ready for action. This method has the advantage that the trailer loaded with poles can be readily detached from the truck and left at any desired location, thus releasing the truck for other work. Also, in case of the load being stuck on a hill or in the mud, the trailer can be readily detached while the truck runs forward and from the top of the hill or from firm ground, pulls the trailer load of poles by means of the winch line.

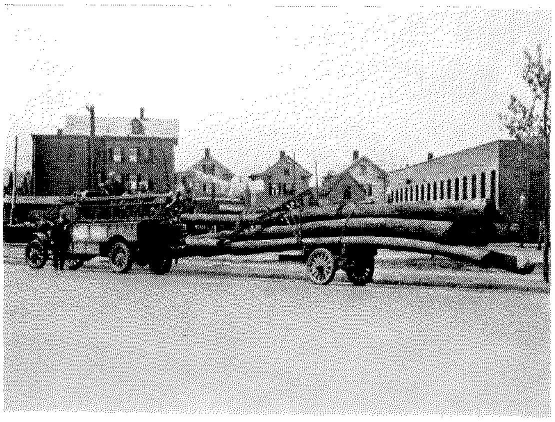

Figure 11—Balanced Load of Chestnut Poles on Pole Trailer

Limiting the weight to conform with requirements of state laws materially limits the size of the load in hauling chestnut and creosoted pine poles. However, in the case of cedar poles, the bulk of the load rather than its weight is ordinarily the limiting factor.

To meet these different conditions, three sizes of pole trailers have been designed, a heavy duty trailer rated at about 8 tons with ample overload capacity, a medium duty trailer rated at 5 tons, and a light duty trailer of 2½ ton capacity for use in districts where it is desirable to maintain a standard tread between the wheels rather than to use the narrow tread dinkeys for the lighter pole loads.

Block Gang Trailer

Figure 12 illustrates a type of trailer which has been developed recently for the use of gangs doing interior block construction work. In a case of this kind, a trailer gang is ordinarily located on a job from one-half day to three or four days, and since the power equipment on a truck would be of no value in connection with placing a cable on the rear walls of buildings, for instance, it is more economical to serve this gang by means of a trailer.

This light type of trailer contains sufficient space for carrying all the necessary miscellaneous tools and materials required in connection with block work and the compartments into which it is divided are such that these articles can be arranged in an orderly and readily accessible manner, thus making for increased efficiency in executing the work.

Concrete Mixers

In connection with the construction of underground conduit and particularly in the work of building concrete manholes, which are now being employed to a rather large extent, it is essential that concrete mixers be available which will be especially adapted to telephone work. Some of the requirements of this service are

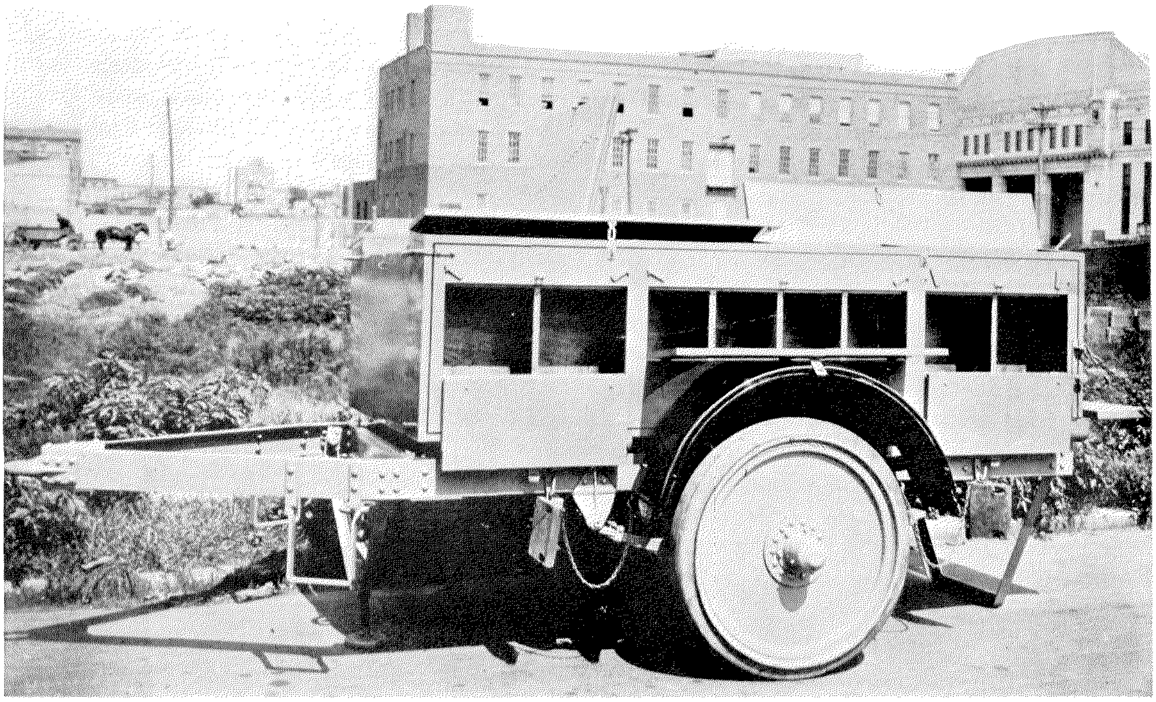

Figure 12—Trailer Equipped with Special Body for Interior Block Construction Work

that the outfit be of light weight, compact, embody maximum portability, and be reliable in operation . The failure of a mixer on a telephone job may seriously handicap the operations of a large gang of men.

Figure 13 shows a commercial type of mixer which has been modified in several respects to meet the particular requirements of telephone construction work.

Units of this type which are now in service are operating very satisfactorily, both from the viewpoint of reliability and adaptability to the work. This outfit will mix as much concrete as ten men and will do it much better.

Figure 14 shows one of the batch mixers in service pouring a concrete manhole, the concrete being uniformly distributed to all sides of the structure by means of a four-way chute.

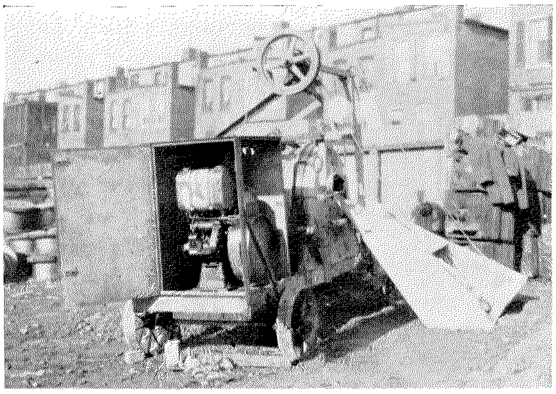

Figure 13—Concrete Mixer Adapted to Meet Telephone Construction Requirements

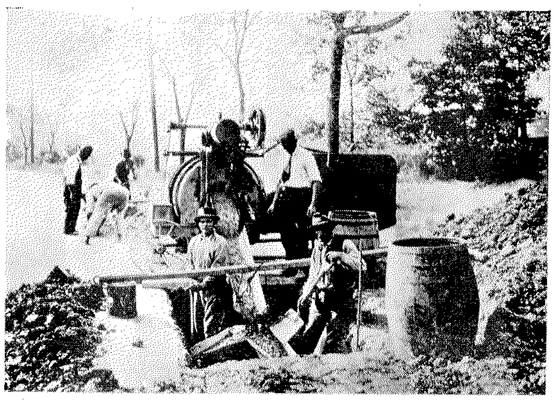

Figure 14—Pouring Concrete Manhole. Note 4-way Chute for Uniform Distribution

In connection with the broadening use of concrete manholes it might be mentioned that the availability of improved compressed air tools has greatly simplified and cheapened the making of any changes that may be required subsequent to the initial construction of the manholes.

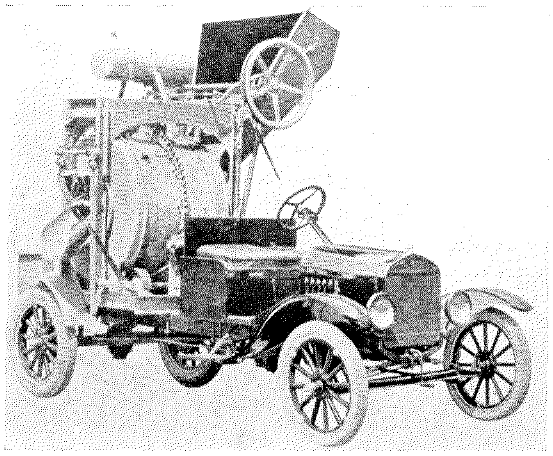

Figure 15—Concrete Mixer on Ford One-Ton Truck. Maximum Portability for Small Jobs

In order to provide a concrete mixer unit having maximum portability and having proper capacity and operating features for telephone work, we have cooperated with the manufacturer in the development of such a unit which is shown in Figure 15. This consists of a batch mixer permanently mounted upon a Ford 1-ton truck chassis and operated through a suitable power take-off from the Ford engine. This unit loads from the ground by means of a power loader and distributes the concrete from the opposite side of the drum through a long swinging adjustable chute (not shown). A small trailer if desired can be used behind the Ford truck to transport the supplies and tools necessary in connection with isolated jobs.

Trenching Machines

Where it is necessary to do a considerable amount of trenching for underground conduit in outlying districts, it is sometimes possible to utilize a trenching machine with marked economy. In fact under normal conditions a machine of this kind will dig trench about as fast as a gang of 50 men.

The machine shown in Figure 16 is a recent development which has advantages over the

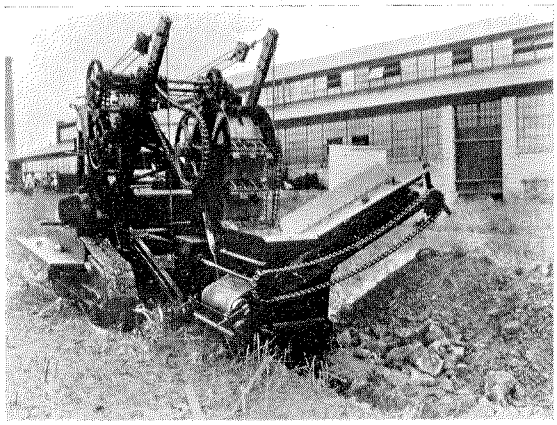

Figure 16—Light Weight Trenching Machine for Use on Small Scattered Jobs

older type units in that the size and weight are such as to admit of its being transported from point to point on a heavy truck or trailer.

Pumps

In handling the water from excavations and also from manholes where splicers are working, the diaphragm pump illustrated in Figure 17 is giving a good account of itself, particularly because of certain features incorporated in the design which especially adapt it to telephone conditions.

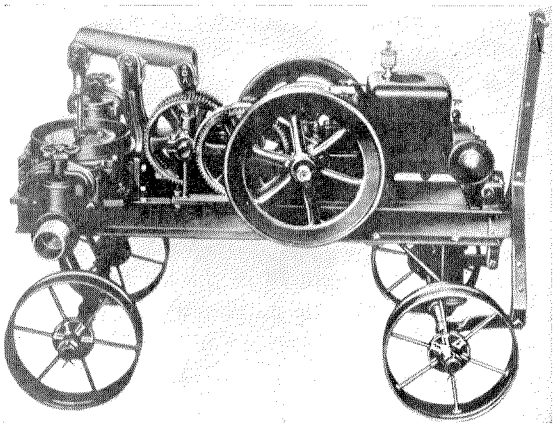

Figure 17—Enclosed Discharge Diaphragm Pump. Capacity One Barrel per Minute

This little unit will pump water at the rate of over one barrel per minute and discharge it through a hose away from the job to any location desired. It will operate all day with practically no attention, upon a gallon or two of gasoline. When pumping under ordinary conditions it will handle water faster than 12 men with hand pumps.

One very desirable feature of the diaphragm pump is that it is self-priming. For instance, if splicers are working in a manhole the pump can be started and the initial volume of water removed, then as seepage water enters the manhole it will be immediately taken up and discharged without any attention from the splicers or helpers.

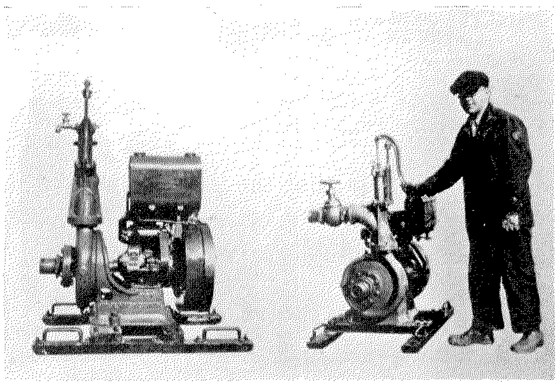

Figure 18—Light Weight Centrifugal Pump. Capacity Seven Barrels per Minute

For handling larger volumes of water there has just been developed, as the result of careful study and cooperation with the manufacturer, a new type of centrifugal pump shown in Figure 18. This unit consists of an air cooled engine similar to that used in the concrete mixers On the end of the engine shaft is mounted the centrifugal pump impeller. This pump casting also forms a base for the engine.

As an indication of the capacity of this pump it might be of interest to note that it would not be possible to get enough men with hand pumps around a manhole to handle water as fast as this unit. It will pump seven barrels of water per minute and mounted on skids as shown it weighs only about 500 pounds.

In the case of trucks which do a considerable amount of underground cable placing in districts where water must be removed from manholes in advance of the cable placing operation, centrifugal pump equipment mounted on the truck is desirable. As soon as the gang arrives at a wet manhole, the pump if promptly applied will remove the water in the few minutes during which preparations are being made for placing the cable, so that ordinarily the gang is not delayed in the least by the water.

There are several points in favor of locating the pump on the running board as shown in Figure 19 rather than in the body at the rear of the cab as has been the usual practice in the past. With the running board installation the water is not carried up into the truck body where it has a tendency to get into the tool and material boxes and equipment and also to cause deterioration of the body. In addition space is economized and the pump is located considerably lower than would otherwise be the case, thus resulting in a reduction of the suction lift for the water between its level in the manhole and the pump impeller.

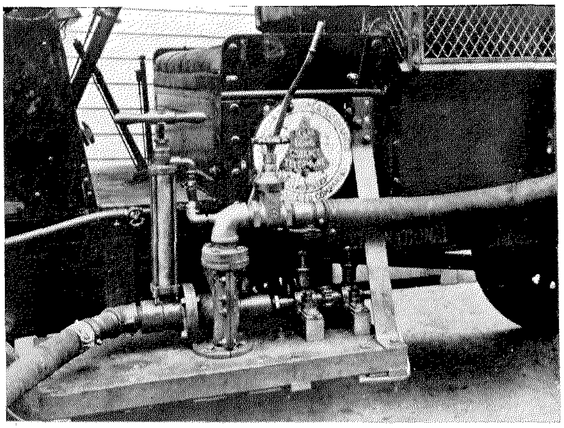

Figure 19—Centrifugal Pump Mounted on Underground Cable Placing Truck

Air Compressors and Compressed Air Tools

Of the many applications for mechanical equipment to offset the scarcity and high cost of certain types of labor such as for excavating, etc., the use of air compressors and compressed air tools is of prime importance in the outside plant construction work. Through special adaptations to meet each peculiar condition, this class of labor saving equipment has been made available for use on such jobs as the opening of all kinds of street pavements preparatory to laying underground conduit, cutting frozen ground, loosening the earth in excavating instead of using picks, drilling rock preparatory to blasting for underground conduit or for pole holes, tamping back filled earth, cutting iron pipe covering from cable, etc.

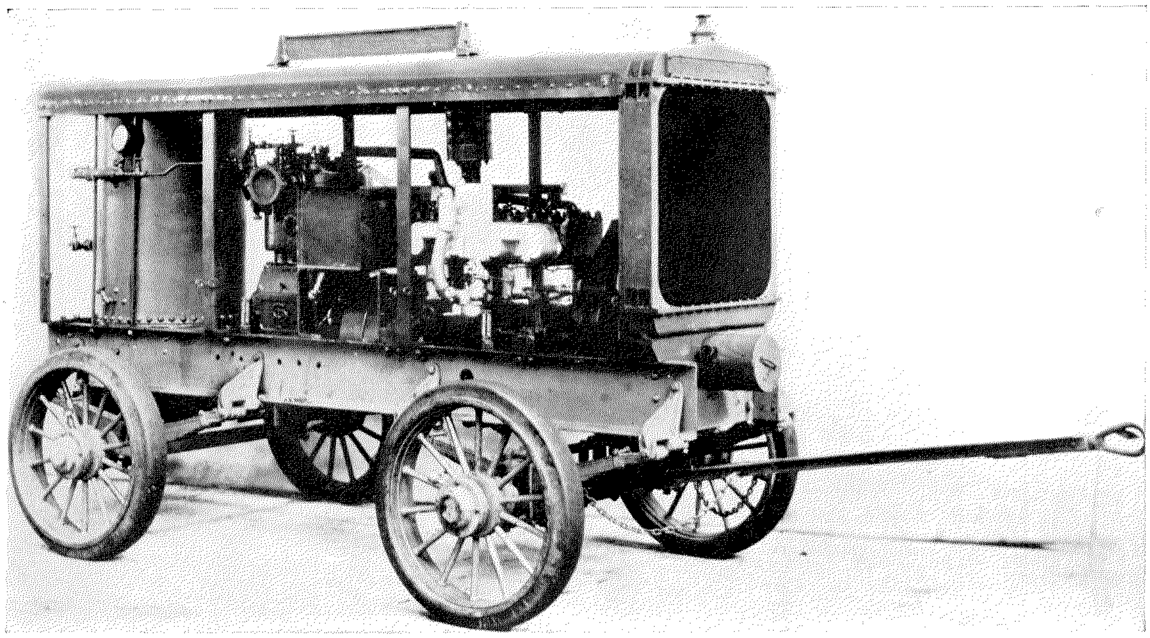

Figure 20—Air Compressor Mounted on Tractor for Maximum Portability

Figure 20 shows a new type of portable gasoline engine driven compressor unit which is being satisfactorily used for the larger jobs of opening street pavements, for rock drilling, etc.

Where trenching work involves cutting through paved streets one compressor unit with three men will ordinarily accomplish as much in a given period of time as 27 men employing former methods.

Figure 21—Removing Granite Blocks and Breaking Concrete Base

In Figure 21 two operators are shown opening pavement which consists of granite blocks set in cement, on a concrete base. One man goes ahead and wedges the blocks loose, while the man following breaks the concrete base. Some pavements of this type are very difficult to open. When the cement filling is of good quality the granite blocks often break before the cement loosens.

Figure 22 shows an operator cutting asphalt pavement. With the wedge-shaped blade cutting at intervals as shown, small cracks are

Figure 22—Air Gun Cutting Asphalt

opened between the holes so that when cross cuts are made square blocks of asphalt can be readily lifted out.

The above illustrations contrast rather strikingly with the old methods of cutting pavements by means of sledges and bars as shown in Figures 23 and 24.

Figure 23—Manual Method of Breaking Concrete. Contrast with Figure 21

In the use of the old manual method of cutting with sledges and bars there is always present a certain degree of hazard to the men. There is the possibility of the striker missing the steel and striking the holder's wrist, also the danger to the men's eyes from flying steel chips. These safety points, of course, are outside the labor saving considerations.

While the labor saving is large in connection with opening street pavements, it is even greater in the work of drilling rock for blasting, where two men and a compressor can ordinarily do as much work in a given length of time as 38 men using hand methods.

In Figure 25 is shown another interesting and efficient application of compressed air tools. Compressed air spades are being used to an increasing extent for loosening hard earth instead of doing this work by the usual pick method. A tool of this kind requires very little air and while this particular application is rather new, it is felt that further study may result in an appreciable saving over hand pick methods.

Compressed air can also be used to advantage in tamping back filled earth. Under certain conditions, however, it now seems that a suitable mechanically operated tamper will probably show greater economy on all except jobs in congested areas where the underground pipe interference is serious or where the trench or opening extends in a diagonal direction, thus often precluding the use of a rigid mechanical device.

Figure 24—Manual Method of Cutting Asphalt. Contrast with Figure 22

The utilization of the portable air compressor is a comparatively recent development undertaken by the telephone companies in cooperation with one of the large air compressor manufacturers.

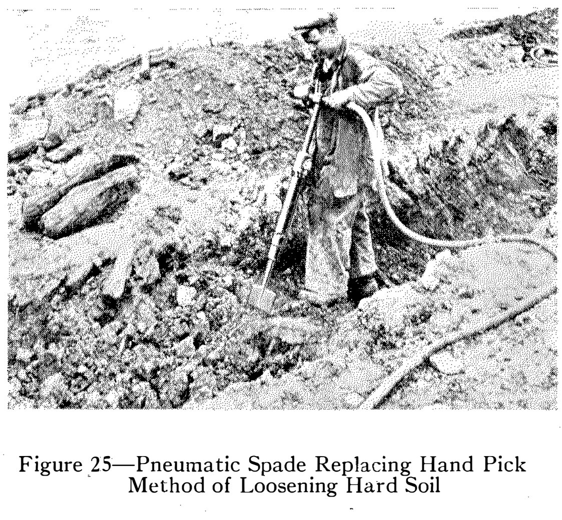

Figure 25—Pneumatic Spade Replacing Hand Pick Method of Loosening Hard Soil

While the large capacity units have reached the stage where they give satisfactory operation, there is a field in the telephone business for a much more compact, lighter weight unit of lower capacity and cost, for such work as the opening of trench for subsidiaries, cutting frost, drilling rock for pole hole blasting, etc. With this in mind there has recently been developed in cooperation with an air compressor manufacturer, a type of compressor which is suitable for operating either one jack hammer for rock drilling or one tool for street opening with a corresponding capacity for other types of compressed air work. It is expected that the weight of this unit can through further study be reduced to such an extent that it will be practicable to mount it upon a Ford one-ton truck and still leave sufficient carrying capacity to handle the necessary guns, steels amd hose for operating. Where there will be practically constant use for this lighter unit it may be desirable to mount it permanently upon the truck, while, in cases where the use will be intermittent, a very economical and convenient mounting can be made upon one of the Army type trailers.

Conclusion

In this article an endeavor has been made to cover in a very brief way some of the more important items of mechanical application which have a place in telephone construction work. The adaptation of mechanically operated tools and other devices to assist in the necessary manual operations will undoubtedly continue to occupy an important place in the work. Further study and development should result in many improvements in the present-day way of doing things which will make not only for marked economies of operation, but for greatly increased features of safety to the men engaged in constructing and maintaining the telephone plant.

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