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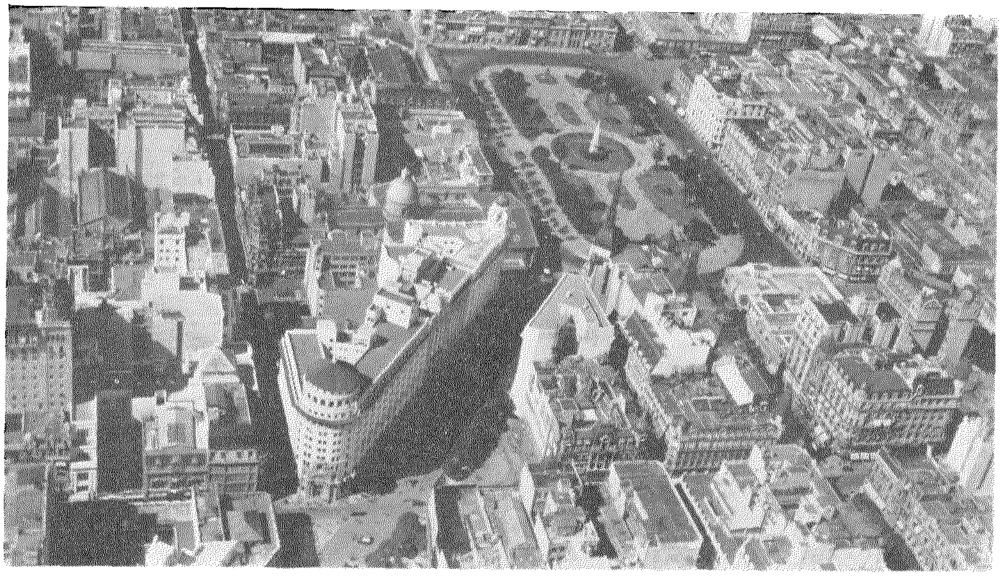
Volume VIII APRIL, 1930 Number 5

CONTENTS

Transmitter Room at Hurlingham, Buenos Aires-New York Circuit



Plaza de Mayo, Buenos Aires, Argentina.

The New York-Buenos Aires Radio Circuit

By H. H. BUTTNER

Assistant Vice President, International Telephone and Telegraph Corporation

THE opening of the radio circuit between New York and Buenos Aires on April 3rd, connecting 277,000 telephones in Argentina, Uruguay, and Chile with 21,600,000 telephones of the United States, Canada, Mexico, and Cuba, marks another step in the world wide linking of the people of the earth by means of telephonic communication. By means of the transatlantic radio telephone between New York and London, the Buenos Aires-Madrid radio telephone described in this journal in February, and now the New York-Buenos Aires radio telephone, the telephone networks of three continents are in actual or potential communication with one another. The New York-Buenos Aires link is unique in being the first two-way telephone circuit between North and South America. Like the New York-London, and Madrid-Buenos Aires, it is a true radio telephone trunk link giving service, not to special booths in the cities where the terminals exist but to the entire telephone networks of the countries concerned.

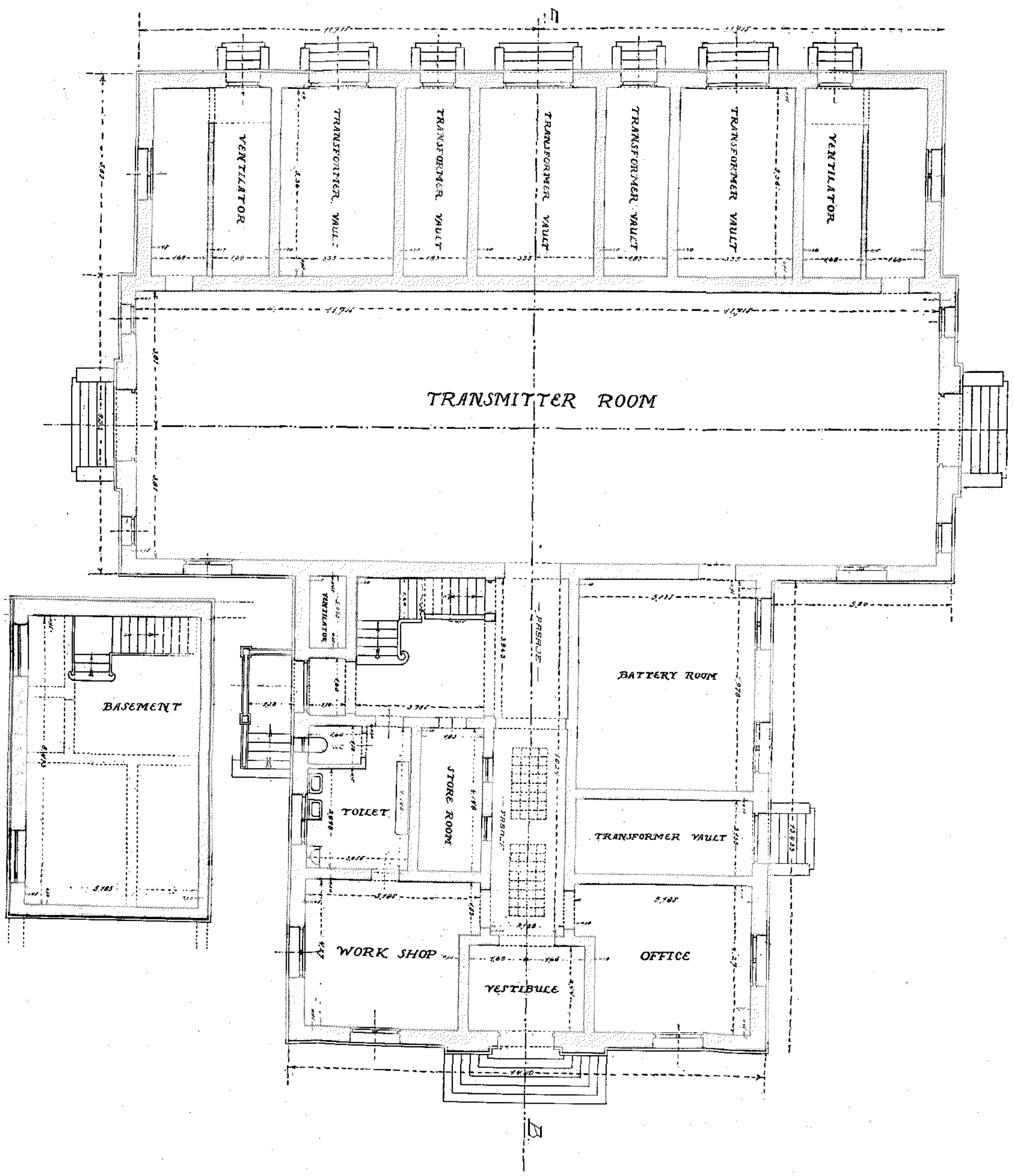
Since the theory of operation of short wave radio telephone links was described in some detail in the recent February edition of *Electrical Communication* on the Buenos Aires-Madrid link, it is proposed in this paper to point out only in a general way the features of special interest.

The radio terminals are located near Buenos Aires and New York. At Buenos Aires the transmitting station is at Hurlingham, adjacent to the transmitter for the Buenos Aires-Madrid circuit, while the receiving stations for both the Madrid and New York services are at Platanos. The New York terminal is operated by the American Telephone and Telegraph Company and is located near the short wave transatlantic circuit terminals; the transmitter at Lawrenceville, N. J., and the receiver at Netcong, N. J. The distance between the New

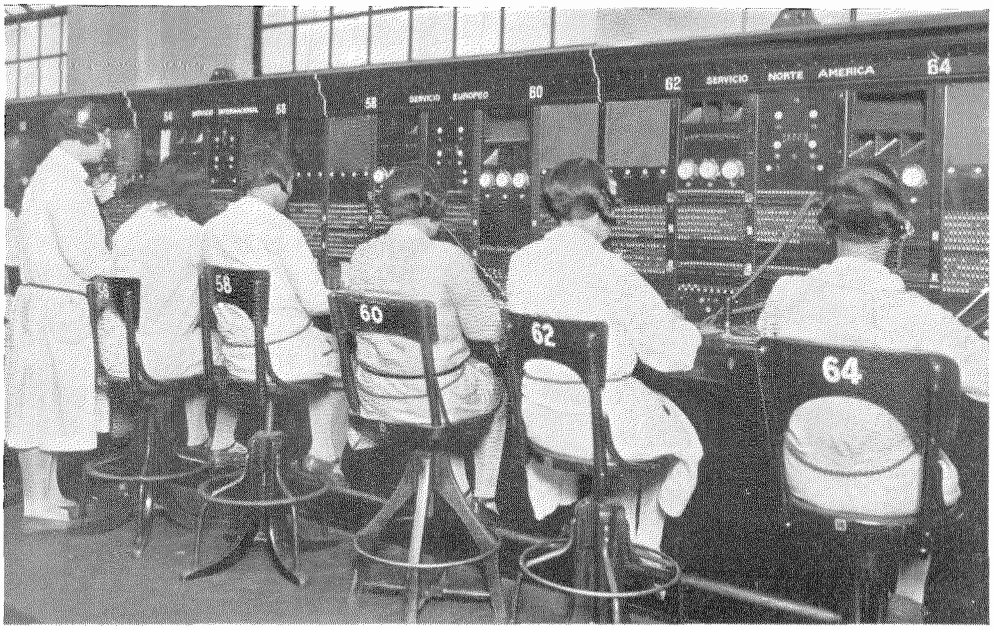
York and Buenos Aires terminals is approximately 8,522 kms. (5,290 statute miles).

Transmitter

The transmitter at Hurlingham is located in a building especially designed to house it. On the ground floor and extending the full width of the building is a large room which contains the motor generator sets. Directly above this room is another of the same dimensions contain-

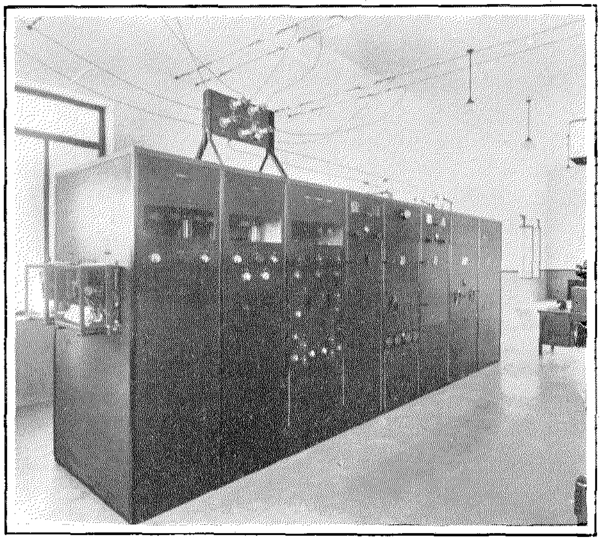


Plan of Transmitter Building.



International Service Toll Board—
Buenos Aires-New York
Buenos Aires-Madrid
Buenos Aires-Uruguay and Chile

Transmitter Building at Hurlingham, Rear View

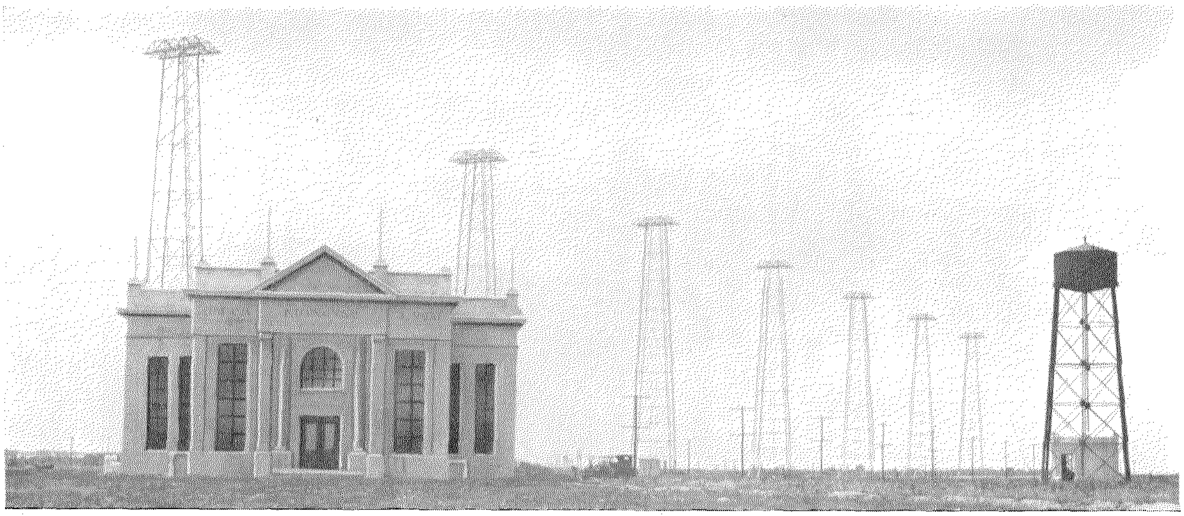


Transmitter at Hurlingham, Buenos Aires-New York Circuit

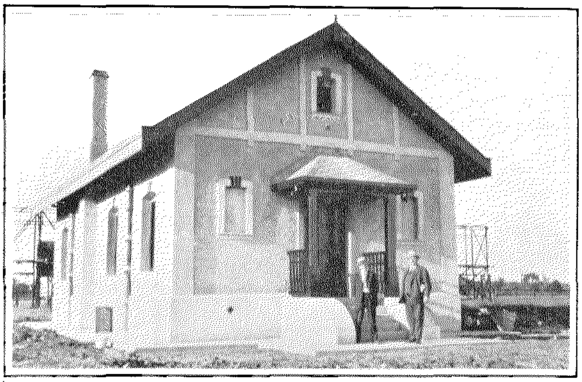
ing the power board and radio transmitter proper. On the ground floor adjoining the power room, are a series of vaults containing high voltage transformers and water cooling units. A vacuum tube rectifier for supplying high voltage to the transmitter is located above the transformer vaults in a small room opening into the main transmitter room. The building is designed for an ultimate of two transmitters.

The transmitter is of Western Electric manufacture. It is of the crystal controlled master oscillator type and electrically corresponds closely with the Madrid transmitter described in the February edition of *Electrical Communication.* The output stage of the transmitter consists of six water-cooled tubes in push pull and delivers 15kw. to the antenna on the highest frequency of approximately twenty-one megacycles (14.3 meters). The installation is especially noteworthy for the precautions taken to insure continuity of service and safety to the operating personnel. Motor generators and power transformers are all supplied in duplicate and so interconnected that in case of failure, any piece of power equipment can be almost instantaneously replaced by spare equipment by throwing a switch. Safety to the personnel is provided by an interlocking system which associates mechanical key operated locks with all switch operating handles and vault inclosure doors. A certain key or series of keys is required to enter any enclosure containing dangerous potentials. The opening of switches, which remove the dangerous voltages from the enclosure in question, releases keys which may be used to open the door. Only when all voltages are shut off and all keys released can the enclosure be entered.

The transmitting antennas employed were described in some detail in the paper, "Short



General View of Transmitter Building at Hurlingham, Buenos Aires-New York Circuit

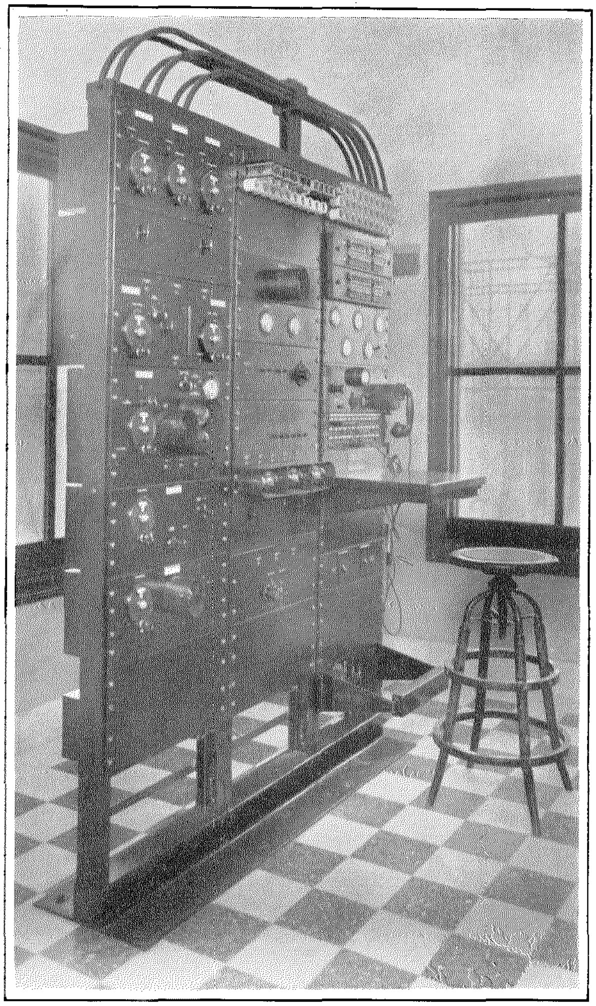


Receiving Building at Platanos, Buenos Aires-New York Circuit

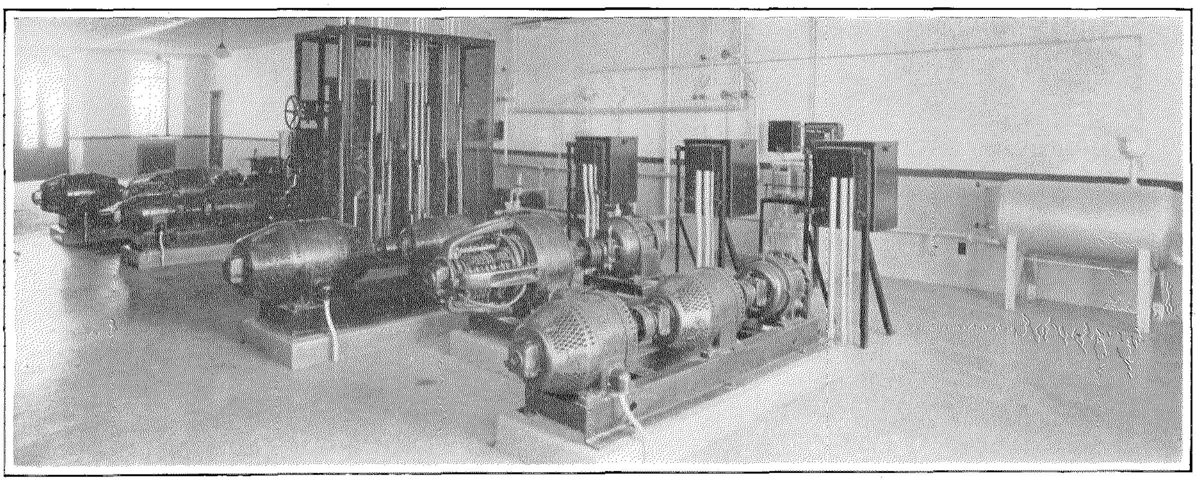
Wave Directive Transmitting and Receiving Antennas," in the February edition of *Electrical Communication.* The frequencies used are approximately 21, 15, and 10 megacycles.

Receiver

The receiver for the New York channel at Buenos Aires is located at Platanos. It is of Western Electric manufacture and is of the superheterodyne type. Two stages of radio frequency amplification are followed by the first detector. An intermediate frequency of 400 kilocycles is employed, the intermediate stage consisting of a band pass filter followed by six stages of amplification, another band pass filter and the second detector. Automatic volume



Receiver at Platanos, Buenos Aires-New York Circuit



Motor Generator Sets at Hurlingham, Buenos Aires-New York Circuit control to minimize the effects of fading is employed. The receiving antennas are of the frame or zigzag type described in the February edition of *Electrical Communication.*

Operators' Quarters—Platanos

Progress in Subscribers' Transmission Apparatus[1]

By L. C. POCOCK, M.Sc., A.M.I.E.E., A.C.G.I.

International Telephone and Telegraph Laboratories, Incorporated

IT is now more than 50 years since the telephone was born to a remarkable career in which it was inevitably destined to become a powerful factor in everyday life. The inevitability of its success lay in its being the most speedy and direct means possible for communication over a distance, and it has, therefore, always been a requirement of telephone engineering that easy, speedy, and comfortable communication should be afforded. To this end, continual development has been necessary and research has yielded an incredible number of inventions which have steadily increased the distance over which communication is possible; today, there is no distance upon the earth that could not be spanned.

New inventions have not only extended the distance over which telephony is possible; some have improved the intelligibility of the received speech, others have permitted an economy in the plant, and every economy in one part of the plant has reacted to make an economy in another more worth while. Thus, it has happened that a certain balance has been maintained, all sections of the plant both large and small being continually forced by study and development to a more economical and higher standard of performance.

The subscriber's telephone set has shared in the general progress that has been made; if it has moved slowly, it is because of the unavoidable inertia associated with the large number in use and the economic difficulties involved in introducing improvements in apparatus which is so widely distributed and sturdily built and which, inherently, has a long life. With these explanations, it may be admitted that the subscribers' equipment is from certain points of view further from the ideal than other parts of the plant, and therefore, capable of the greatest improvement. Improvements are already on the way, and though they must permeate slowly into the established system, progress is both steady and certain.

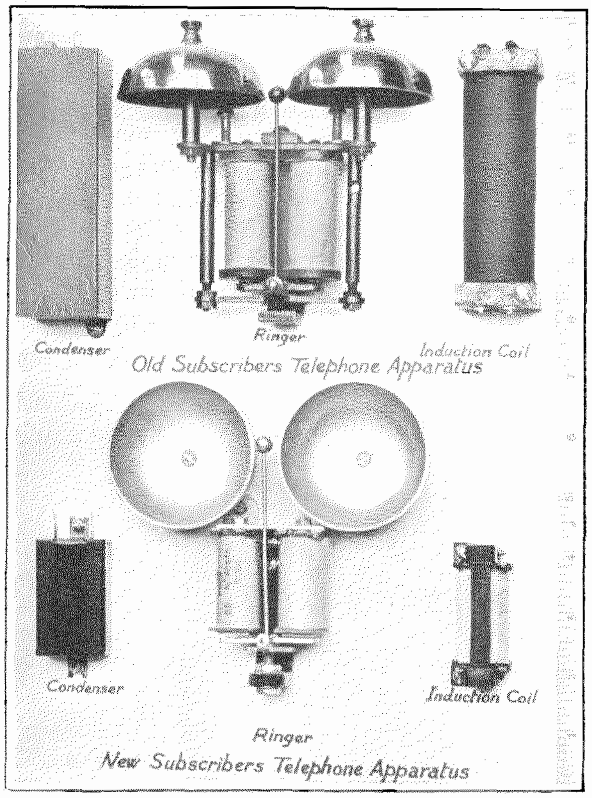


Figure 1—Subscribers' Old and New Telephone Apparatus.

As of interest in connection with the historical development of subscribers' apparatus, it may be noticed in passing how the tendency towards more comfortable and convenient apparatus has been evidenced by the development of central battery signalling in place of the hand generator, by the employment of a separate bell box with only the minimum of apparatus (transmitter, receiver, and switch hook) on the subscriber's desk, and finally by the development of handsets, or as they are sometimes called, "microtelephones." With the introduction of handsets comes a return to the more economical arrange-

[1]Presented before World Engineering Congress, Tokyo, Section 6, October 30, 1929.

ment of apparatus in a single unit, the induction coil condenser and ringer which for years have hardly changed in appearance, being now made small enough (Figure 1) to be enclosed in a neat set not occupying appreciably more desk space than the pedestal type of desk stand.

The convenience of handsets in preference to fixed transmitter desk sets must have been recognised from very early days, as is witnessed by Figure 2, which is a photograph of what must have been a crude and early model of a handset, probably made up for experimental purposes; the transmitter is an electromagnetic instrument similar to the receiver.

The ordinary fixed transmitter desk stand is commonly placed at arm's length in order to leave the desk top as free as possible for papers and documents. In order to use the telephone

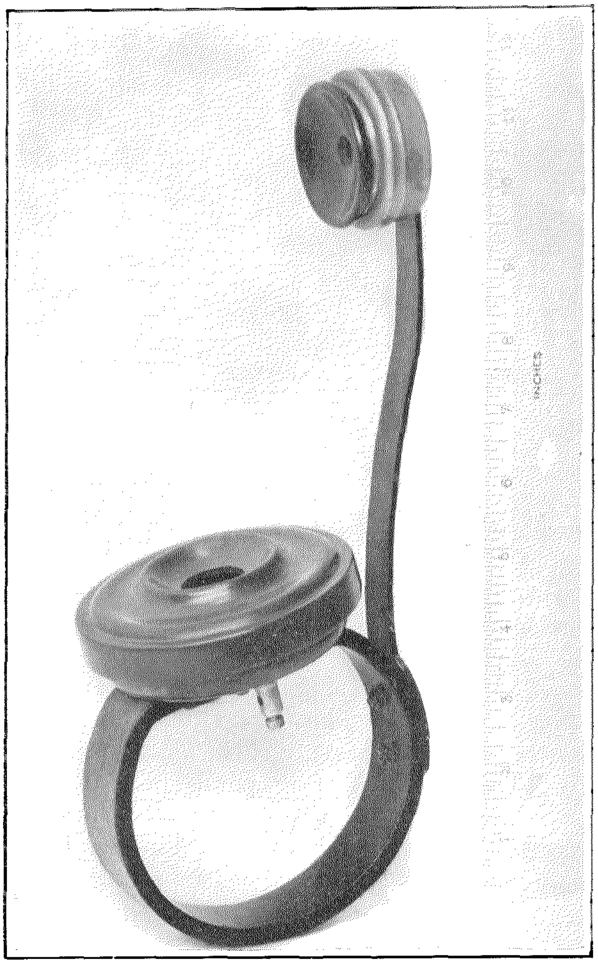


Figure 2—Early Handset Model.

the whole instrument weighing $2\frac{1}{2}$ kg. must be lifted across the table before raising the receiver to the ear; this procedure is tiresome and irritating and leads occasionally to the subscriber shouting at the transmitter across the table, a practice which results in extremely bad transmission. Where a handset is installed, a cradle desk stand is naturally and properly placed at arm's length and there is no hardship in picking up the handset weighing about 500 grams and carrying it directly to the ear.

The second and equally important advantage of the handset lies in the freedom of movement which it permits; not only does it allow the speaker to carry on conversation while moving about or searching for papers in the drawers of his desk, but it allows him to lean back in his chair and talk in comfort. Compare this with the severe and erect attitude necessary while talking into a fixed transmitter when business men will often be observed to be in a posture less relaxed even than at other times of working at their desks. It is probably not too much to say that to provide an instrument which enables a busy man to lean back and relax when using the telephone is to do much to ensure that telephone communications shall be treated courteously and sympathetically, resulting in improved understandings and increased business.

The justification on the grounds of comfort for the employment of handsets has been seen to be so overwhelming that a firm demand for them has been established.

Difficulties peculiar to handsets may be classified as:

1. Due to mobility, *i.e.*, the necessity that the transmitter shall operate satisfactorily in any likely position. Under this heading:
   (a) The efficiency should not vary excessively with position.
   (b) The resistance should not vary excessively with position, and in particular, "opening circuit" must not occur.

2. Due to union of the transmitter and receiver on a handle:
   (a) Howling may result from the communication of mechanical vibrations from the receiver to the transmitter.
   (b) The distance between the lips and the mouthpiece is practically fixed by the user's head dimensions; close-up speaking in order to get the maximum effect is, therefore, in general, impossible, and the transmitter must therefore have good efficiency when the speaker is not quite close up to it.

The Practical Ideal Set

As a convenient method of developing the subject of this paper, it is proposed to consider the factors which must be taken into account in aiming at an ideal set, examining the amount of ground that has been covered and the prospect of further improvements.

The specification of the ideal set is not an easy matter, if the conception is restricted to such practical conditions as will make it useful; a single example will show the difficulty. Consider what degree of efficiency is required in the transmitter and receiver and the first conclusion might be that both should be of very much higher efficiency than apparatus now in use. Such a requirement would entail two disasters, one within the subscriber's set and one without. The former would be the excessive side tone requiring a perhaps impossible restriction on the side tone of the set, and the painfully excessive volume received over short lines. The external disaster would lie in the amount of crosstalk likely to occur in the existing plant and this would take the restrictions of the ideal set specification outside the sphere of the subscriber set proper.

It will, therefore, be convenient to dilute the ideal to the extent of considering the subscriber's set that should be built to work with existing telephone plant.

The properties to be considered are listed below. As has been indicated in the example above they are inter-connected so that there is hardly one element that can be varied without in some way affecting one or more other elements.

Transmitter.

- Efficiency of transmitter.
- *Variation of efficiency with position.
- *Microphonicity or variation of efficiency with talking distance.
- Articulation efficiency of transmitter.
- Resistance of transmitter.
- *Variation of resistance with position.
- *Liability to open circuit momentarily when jarred, thus giving false signals at the exchange or interfering with automatic apparatus.
- Life of transmitter.
- Protection of transmitter from moisture (especially in certain climates).
- Burning.
- "Packing" or development of an inefficient state.

Receiver.

- Efficiency of receiver.
- Articulation efficiency of receiver.

Transmitter and Receiver.

- Side Tone.
- Pick-up of room noise.
- *Liability to howl, or to distort as a result of coupling between transmitter and receiver.
- Relation between transmitting and receiving efficiency.

Subscriber Set.

- Frequency characteristic of subscriber's set (i.e., from transmitter terminals to line and vice versa).
- Transmitter, Receiver and Line, terminal impedance.

In the above list those items marked with a star represent features which are peculiar to or which require special attention when the subscriber's apparatus includes a handset.

The ideal set for most purposes in the light of what has been said above, will be taken to comprise a handset mounted for economy on a desk set which contains the circuit apparatus.

In order to elaborate this ideal, certain standards of performance are required, and it will be convenient to refer the performance of any set to the performance of the set in the circuit A shown in Figure 3. This represents a set using a fixed transmitter and ordinary type of telephone receiver connected in a very commonly used circuit. The degrees of comparison with circuit A are expressed in decibels, a unit nearly equal in magnitude to the old mile of standard cable, but independent of frequency.†

In considering the transmitting efficiency of the ideal set, it will be convenient to suppose that the efficiency varies with the current supply as controlled by the loop resistance in a given case in the same way as the efficiency of the

†When two powers (electrical, acoustical, etc.) are expressed as the ratio P_1/P_2 they are said to differ by N decibels where $N = 10 \log_{10}\frac{P_1}{P_2}$.

transmitter in the Comparison Circuit A. Ideally the less the efficiency varies with current supply the better, but no such absence of variation or even considerable reduction of the variation is possible as long as carbon transmitters are considered. If within these limitations it were pos-

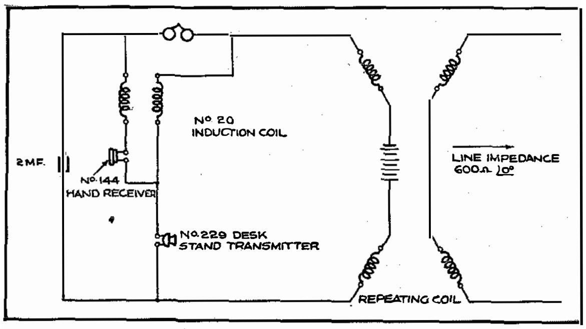


Figure 3—Reference Set—Circuit A.

sible to augment the transmitter efficiency by any desired amount, how much increase of efficiency would be tolerable. The answer is that for straightforward connection to existing lines with a certain number of short loops no increase of efficiency over the transmitter standard of circuit A is desirable on account of the side tone on short loops and the high speech volume received on short connections. If anti-side tone circuits are adopted the answer is unchanged, but if the shorter loops are furnished with extra resistance to reduce the current supply, the answer is altogether different, since both the side tone and the excessive volume transmitted are simultaneously corrected.

The controlling factors are that the electrical speech level at the local exchange and the side tone should not be greater than the corresponding quantities in circuit A. If the transmitter in circuit A could be increased in efficiency, the output to the trunk line could be maintained constant by inserting suitable resistance in the local loop. The side tone would then increase slightly because the actual transmitter output would have to increase by the amount of the speech frequency transmission loss in the added resistance, but this would be partly offset by a contrary effect due to the higher impedance into which the set was working, so that the side tone and output to trunk may be regarded as having been simultaneously kept substantially constant by the addition of suitable resistances. The important conclusion to be drawn is that the effect of increased instrument efficiency will be to require the introduction of equalisation in the short loops, rather than to necessitate the use of anti-side tone circuits.

In view of the number of anti-side tone sets recently developed, it will be worth while considering further the arguments for and against an anti-side tone subscriber set.

Side Tone

The question as to whether any side tone is desirable and if so, how much, is one of considerable difficulty. The point involved is principally whether, on account of the higher transmitter efficiency on short loops and the resulting higher side tone, a special anti-side tone set is to be used for *all* stations, since it is generally undesirable to stock two different types of set. Stated in this way the problem is partly an economic one, the (generally) increased cost of the anti-side tone set being balanced against other methods of reducing side tone which can be applied to stations individually in which side tone is objectionable.

Before entering upon the arguments in either direction a few facts in regard to side tone will be considered.

When one is speaking through the ordinary air medium the speech intensity is adjusted automatically according to an estimate of the distance at which the listener is placed. The intensity is further controlled, or perhaps the intended speech intensity is adjusted in accordance with the way in which the speaker hears his own voice. For example, anyone wearing headphones replies in a loud voice when spoken to, while conversation carried on in the presence of noise is conducted in a loud voice with the subconscious intention of maintaining a margin for the speech level above the threshold of hearing for speech in the presence of the noise.

These remarks apply to the artificial hearing of the voice in telephony through the local receiver. The speech intensity adopted in speaking into the telephone is partly controlled by the amount of side tone, and partly by the intensity with which the distant subscriber is received, that is the estimate of distance which the speaker unconsciously forms. It appears, therefore, that side tone properly used may contribute to a desirable adjustment of the speaking intensity.

Experiments on this subject are naturally difficult, involving as they do, observations upon the subconscious adaptions of the persons observed. Experiments have been made, however, and have indicated that the speech intensity adopted is in the average related to the amount of side tone approximately as shown by Figure 4. It will be seen that taking the zero on the side tone scale as about the maximum occurring in practice, a reduction in side tone of about 20 decibels would lead to an average increased speech intensity of 4 decibels. The trend of the curve for greatly increased side tone is uncertain, because some of the persons on whom the observations were made were conscious of the side tone as a noise which they endeavoured to shout down. This was not always the case, however, one speaker, for instance, dropping his voice 12 decibels as the side tone increased from 0 to + 20.

The application of this curve to some typical cases will help in an appreciation of the part played by side tone in practical telephony.

1. *A Local Call between Two Subscribers on Short Loops.*

In this case the transmission is adequate—too loud, in fact. The two subscribers are nearly deafened by each other, with the result that they do not realise how loudly they are talking. In such a case, plenty of side tone exercises a certain amount of restraint and a particularly low side tone might be harmful to transmission.

2. *A Call (Local or Otherwise) between Two Subscribers on Long Loops.*

In such a case either a side tone or anti-side tone set has relatively little side tone, say about −10 decibels on the curve of Figure 4 and an improvement in transmission of 1 to 2 decibels might be expected from slightly louder speaking if anti-side tone sets were used. If the reception is faint, however, this fact will have a stimulating effect upon the speech intensity, probably to a considerably greater extent than 1 or 2 decibels.

3. *A Call (Local or Otherwise) between two Subscribers. One A on a Long Loop and one B on a Short Loop.*

In this case A has a transmitter operating inefficiently and B has a transmitter operating efficiently. The transmission equivalent in the direction A to B is, therefore, greater than in the direction B to A.

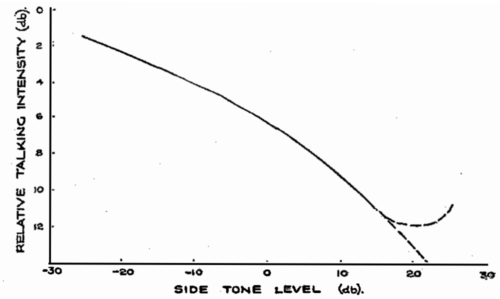


Figure 4—Relation Between Side Tone and Calling Intensity.

According to what has been said B, hearing A more faintly than A hears B, will be inclined to speak more loudly and vice versa, thus increasing the difference in effective transmission equivalents in the two directions. The effect of side tone will evidently be in the direction of restraining this tendency towards inequality of transmission, by causing B to speak more quietly while having relatively little effect upon A.

The feature which sometimes makes side tone objectionable or even painful is not so much the hearing of the natural voice at a rather high level, but the hearing of isolated syllables or vowel sounds at a level far greater than the level of the rest. These take the speaker unawares and are genuinely objectionable. For example, side tone may be scarcely noticeable in such a sentence as:

"When I speak in this way."

while, on account of the transmitter and receiver resonances which are commonly found in the region 800–1,200 p.p.s. accentuating such vowels as "ah," "aw," the same apparatus may be found to have painful side tone when the sentence spoken is,

"Father saw an owl in Oxford."

It follows that improvement made in the frequency response characteristics of transmitters and receivers will tend to make side tone less objectionable. In this connection experiments have indicated that very high side tone is not objectionable when it is high quality speech entirely free from resonant and other distortions.

It may be objected that the room noise picked up by the transmitter and present in the side tone interferes with reception in all cases, that is on any length of loop. This is undoubtedly true, and is the most potent argument that can be brought forward in support of the anti-side tone set, though the interference may, perhaps, be much less when the noise is one to which one is accustomed than when it is an unaccustomed noise such as is usually employed in experiments. The importance of the interference depends upon the amount and character of the noise as much as upon the side tone characteristics of the set.

A long loop generally reduces the transmitter efficiency (by reduction of the current supply) by more than it reduces the received volume of speech, so that for a given amount of room noise the interfering effect will be greater on

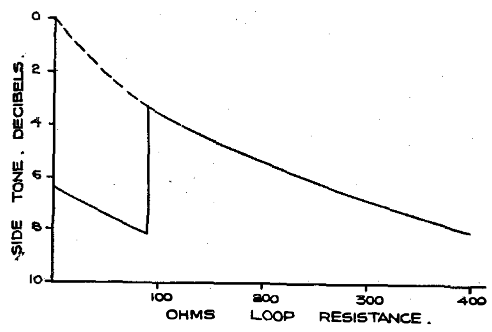


Figure 5—Variation of Side Tone with Loop Resistance.

the shorter loops, and, therefore, any systematic reduction of the efficiency of the shorter loops (equalisation) will ameliorate the receiving conditions in the worst cases. When this has been done, any residual interfering effect due to noise argues in favour of an anti-side tone set, but since all noise is objectionable there is a stronger argument for the reduction or removal of the noise itself. This in the broadest sense is the proper treatment and is a subject now receiving considerable attention in respect to the street noises in big cities.

Summing up the arguments it will be seen that side tone provides a control of the speech intensity which is generally in the right direction, that no increase of side tone is likely to result from future improvements in transmitters and receivers, as greater volume cannot be tolerated on short lines, whereas improvements in transmitter (and receiver) quality will reduce the objectionable character of side tone. A movement towards some degree of equalisation of the transmission equivalent of local lines may be expected in the form of a reduction of transmitting efficiency (and consequently side tone) on the shortest lines; such a movement will be imperative should marked improvement in the efficiency of transmitters be brought about.

A very simple and convenient way of effecting at once both a certain degree of equalisation and a decided reduction in side tone is to alter the connections of circuit A so that the receiver terminal shown connected to the transmitter is transferred to the other side of the transmitter, a change which can easily be made even when the set is installed on a subscriber's premises. If this is done on all loops of less than 90 ohms resistance the side tone (expressed in relation to the side tone of circuit A) will be reduced as shown by the stepped down portion of the curve (Figure 5). At the same time there will be for the short lines a reduction of transmitting efficiency by 3.5 decibels, which tends towards equalisation, and an increase of receiving efficiency of 1 decibel, which tends to discriminate in favour of the received speech against room noise. The side tone reduction connection is seen, therefore, to operate in a very satisfactory manner, reducing the side tone 4½ to 6 decibels, increasing the margin of received speech to side tone noise by 5½ to 7 decibels and reducing by 3½ decibels the transmitting efficiency which is unduly high compared with that of longer loops.

This procedure has been successfully adopted for many years by the American Telephone & Telegraph Company.

The subject of side tone has been discussed rather fully. It is important, and will appear again in succeeding pages, often as a limiting factor and in such a way as to suggest that an anti-side tone set would make everything easy;

but the interlocking of the various elements contributing to the harmonious working of a subscriber's set must not be forgotten. If it has been decided either on technical or economic grounds not to employ anti-side tone sets, then side tone conditions must be carefully watched as one of the factors having a predominating influence. If anti-side tone sets are employed, the element of control over the speaking voice is lost and there may be complaints of excessive reception loudness. In either case any unusual set installed at the moment may be an embarrassment and an obstacle to the adoption later of transmitters and receivers of improved performance, while a standard type of set can by a simple alteration of connections and without extra cost take care of any exceptional conditions calling for reduced side tone.

Microphonicity of Transmitter

This term is used to describe the variation of transmitter efficiency with talking distance. The mouthpiece used determines the pressure on the diaphragm due to sound and generally modifies or distorts the sound by selective treatment of certain frequency ranges. As the talking distance is changed the pressure on the diaphragm may be supposed to vary approximately proportionally to the pressure with which the sound reaches the mouthpiece opening. The transmitter output will not vary according to the pressure on the diaphragm; the microphonic sensitivity of carbon is lower for lower amplitudes, and the loss in output for increasing distance between mouth and mouthpiece is, therefore, greater than would be expected from the reduction in air pressure at the mouthpiece. Comparatively little control can be exercised over the microphonic loss, since a transmitter of a specified resistance and efficiency must have a determined degree of agitation, that is to say, it is working at a given point on the curve relating amplitude of mechanical motion to voltage generated. The reduction in electrical output for any particular reduction of input is therefore determined by the curve which is an approximately constant characteristic of carbon.

Transmitters used in handsets are, like other transmitters, spoken into from various distances, but are unlike fixed transmitters in that this variation is unavoidable. The receiver, because of its small sound output and because the person using it is the judge of its performance is placed on the ear and the transmitter is then automatically located at some distance from the mouth depending upon the shape and size of the user's head. If the handset is made rather small so as to decrease the talking distance in all cases, a certain number of people with rather large heads will not be able to get the mouthpiece opposite their mouth at all and will generally place it right underneath the chin, where it will give very poor transmission. On the other hand, if the handset is made larger there will be a drop in transmission for every user except the small number of out size type, who as a result of the increased length are enabled to bring the transmitter opposite the mouth.

In order to determine the best length to be adopted for a handset the Bell Telephone Laboratories made measurements on the heads of over 4,000 people and plotted them in such a way as to show the position of the mouth in relation to the centre and plane of the ear. The frequency of occurrence of different positions of the mouth is illustrated by the vertical height of the solid model of which a photograph is reproduced (Figure 6). A comparatively small proportion of users represented by the cut away portion will be unable to use the particular handset shown in silhouette with the transmitter properly located to the mouth. The peak of the model representing the most frequently

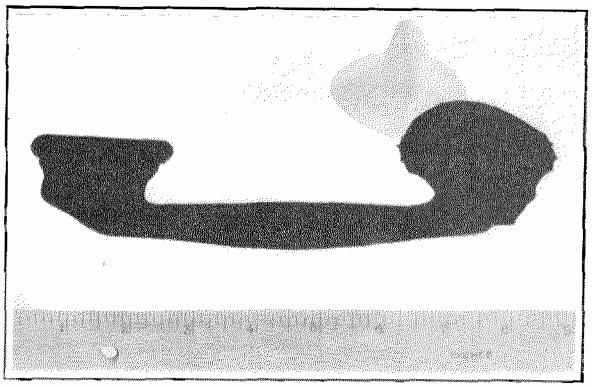


Figure 6—Model for Determining Best Dimensions of Handset.

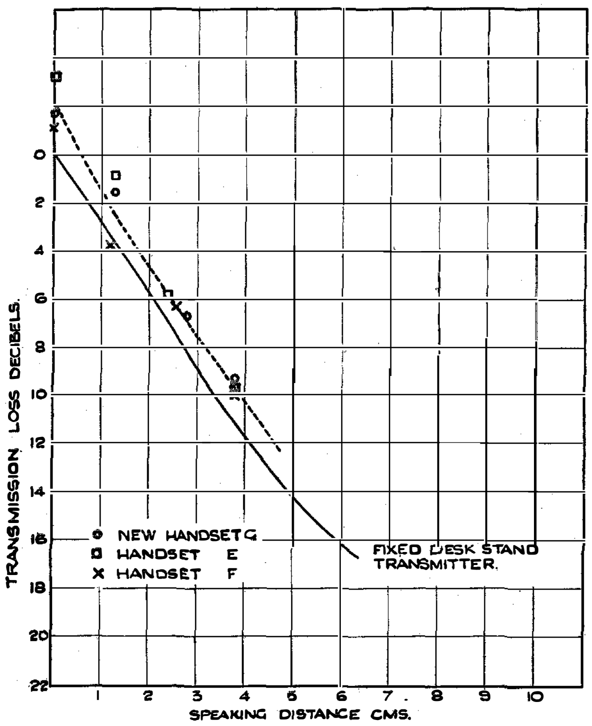


Figure 7—Microphonic Loss Curves for Transmitters.

occurring mouth position is about 1.2 cm. from the centre of the mouthpiece opening.

As an illustration of the kind of variation of efficiency with distance, the results of experiments made on various transmitters are shown in Figure 7, where the full line curve is for a fixed type transmitter. The experimentally obtained values for three different types of handset lie so close together within the limits of experimental error that one curve practically parallel to the curve for the fixed transmitter has been drawn to represent the whole data.

Variation of Efficiency and Resistance with Position

Handsets are liable to be used in a wide range of positions, and it is obviously desirable that the efficiency should change as little as possible with the position of use. In the same way, the transmitter being a resistance operated device must have resistance, but the resistance adopted should vary as little as possible either with position or spontaneously as the result of expansion and contraction of the carbon granules and their containing chamber. Any considerable increase of resistance lowers the receiving efficiency of the set (when the transmitter and receiver are effectively in series), is liable to interfere with the exchange signalling and connecting devices, and may also promote the developing of "burning," that is, the continuous production of transmitter hissing and crackling noises which may make speech reception impossible. Amongst the positions of use of a transmitter must not be forgotten the horizontal position in which it is commonly laid on the cradle or any position in which it may normally be laid down on the table. These positions may be quite different from the speaking position and some difficulty is encountered in designing a handset which shall fulfill the other requirements and yet avoid high resistances in these positions. The importance of avoiding high resistance in the horizontal position is considerable, because at the moment of placing the handset upon the cradle it is submitted to an inductive discharge as the circuit is broken and it is also jarred as it strikes the cradle; both effects promote the development of burning (see Figure 12). A similar consequence follows from the momentary passage of ringing current which may occur as the handset is lifted to answer a call.

The unsatisfactory service given by handsets having bad positional effects was recognised as early as 1907, when American patent 855394 was taken out to cover a transmitter of the solid back type mounted in a handset in the manner shown in Figure 8A. This arrangement is open to certain objections but does reduce the positional effects over that part of the range of speaking positions most used. The next and most notable step was taken by the Bell Laboratories* by inverting the transmitter as shown in Figure 8B. This arrangement is very effective but renders precautions desirable to prevent the ingress of moisture from the breath to the granular carbon and to the paper leaves which are a feature of this transmitter. The arrangement also necessitates rather special weight being given in the design to the factors controlling the face down resistance which, for the construction shown, is evidently liable to be

*British Patent 263954.

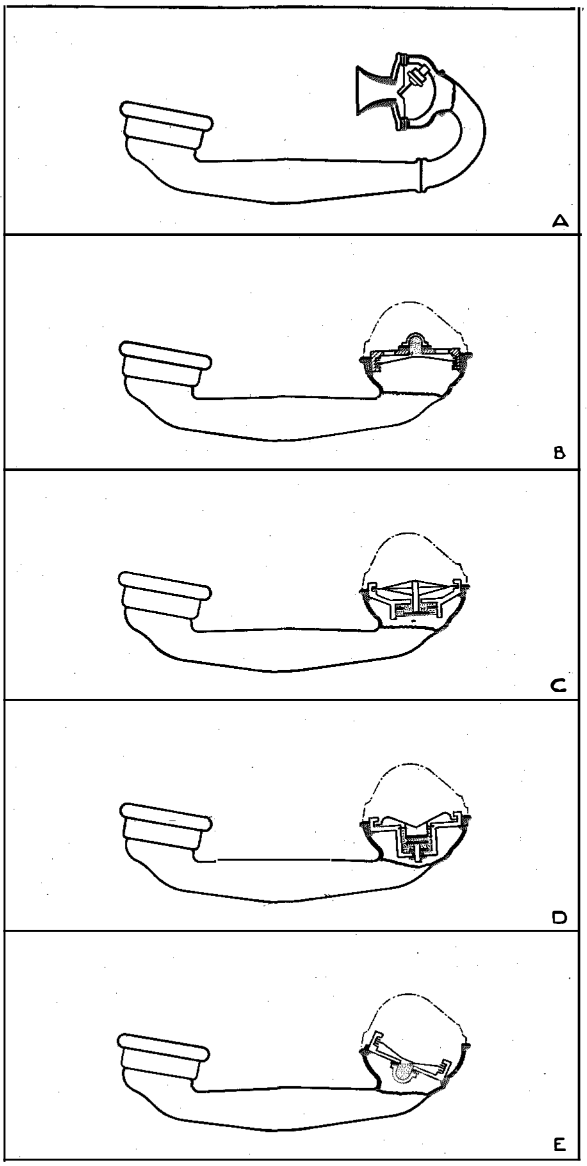


Figure 8—Devices to Secure Good Positional Efficiency in Handsets.

higher than in other positions. Figures 8C and D illustrate two recent British patents** having the same object in view; in case C the transmitter button is inverted and driven by a rod passing through the carbon chamber and in case D a normal type of construction is shown, except that the electrodes are rather deeply immersed in the carbon.

Figure 8E shows the arrangement of a handset to be described in greater detail later.* The transmitter is placed in such a position that its maximum resistance occurs in a position which cannot be adopted while the handset is spoken into, and is unlikely to occur in a position of rest.

The various positional effects which have been referred to are illustrated in Figures 9 and 10, taken from records of development work on different transmitters.

Figure 9, showing the variation of efficiency of handsets with position, exhibits in the case of curve F a minimum value when the plane of the transmitter is vertical. This is quite characteristic of transmitters containing plane parallel electrodes and would seem to be due to mechanical packing of the carbon in the absence of any upward component of the agitating force. (The curves are taken from various sources and may be erroneous as regards their absolute relative positions.)

Figure 10 shows the maximum "breathing"** resistance of several different types of transmitter under a given current condition and for various positions of rest. The resistance values in which the curves terminate on the extreme right are approximately the maximum resistances which occur when the handset is horizontal

**Nos. 308630, 308638.

*British Patent 304843.

**This term is used to describe spontaneous changes of resistance in a quiescent transmitter, resulting from the expansion of the carbon and carbon chamber when the current is first switched on or otherwise altered.

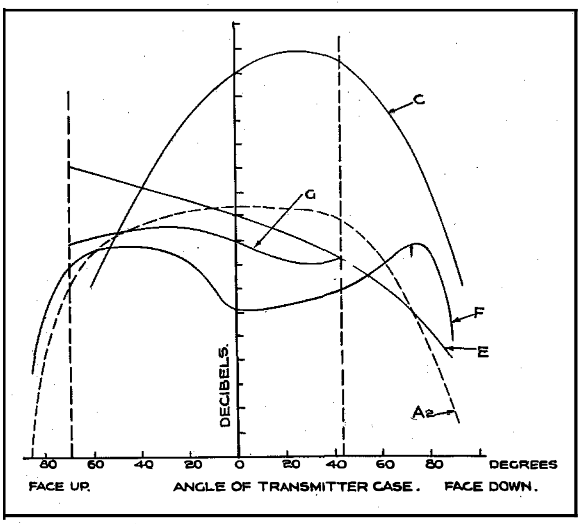


Figure 9—Variation of Transmitter Efficiency with Position.

as on the table or on its cradle. The region of positions likely to occur while the handset is spoken into in service is between the two vertical lines on the figure, the left-hand part of this region being the most used.

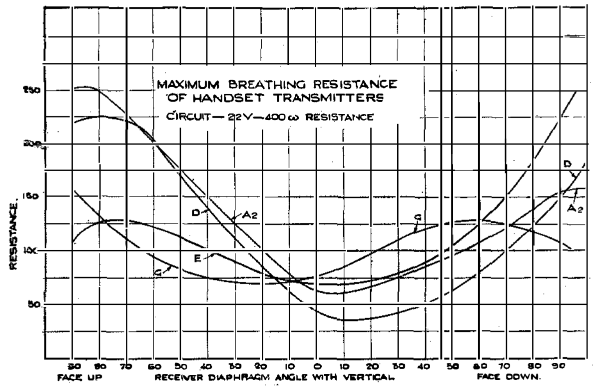


Figure 10—Maximum Breathing Resistance of Handset Transmitters.

In this connection special attention is directed to curve G; it will be noted that the total variation of resistance is the least for this curve and that low resistance has been secured in the important talking position and in the face down position at the expense of a slight increase in resistance for the less normal talking position.

Maximum Momentary Resistance

Another difficulty peculiar to handsets is the more or less violent treatment they may receive, as, for example, when put down roughly on the table when the user wishes to leave the phone during a call. The sudden blow throws the transmitter into violent agitation, causing a momentary high resistance capable in some handsets of causing the supervisory signal to flicker or, in an automatic system, the exchange apparatus to receive a false impulse if such a jar occurs while taking the handset from its cradle or for any other reason before the dialling is completed.

Packing

Carbon transmitters are liable to "pack," that is, to assume a low resistance, inefficient condition which may have its origin in mechanical settling together of the granules or it may be produced by a coherer action resulting from the momentary passage of a high voltage, such as may be produced by an inductive discharge when the circuit is broken. Mechanical packing does not occur in well-designed and well-made transmitters, but electrical packing is readily produced by operation of the switch hook (*e.g.*, to make a second call), while a handset is held in the hand unless special precautions are taken. In some cases the inefficient condition may still persist even though the subscriber speaks fairly loudly into the instrument; it is then necessary to shake or jar the handset in order to re-establish the efficiency.

Electrical packing produced by operation of the switch-hook is interesting as being essentially a radio frequency phenomenon; it can accordingly be reduced or prevented by the arrangement of suitable chokes between the switching point and the transmitter, or by a small condenser shunting the transmitter.

Transmitter, Receiver, and Line Terminal Impedances

The transmitter, receiver, and line terminal impedances of a set are intimately connected with each other and with the induction coil ratio and the receiver impedance.

The impedance at the line terminals of the set should be so chosen that the reflection loss is a minimum for that length and type of line for which a transmission gain is economically of greatest value; *e.g.*, if there are a large proportion of subscribers at such a distance from the exchange that they can just be reached with 24-gauge cable, without reducing the transmitting efficiency below the permitted value, there may be a sufficiently large number of subscribers brought into the 24-gauge cable region by eliminating the reflection loss for this particular kind and length of loop, to justify doing so. Evidently there will be some particular length and gauge of cable for which the concentration of subscribers will be such that the saving in copper effected by a small extension of the zone will be greater than for a similar extension of any other zone. As it is necessary to standardise the set impedance, the varying conditions cannot be met in an ideal manner in different networks, but a reasonable guess at the most probable answer suggests that the set impedance should be conjugate to the line impedance when the line consists of about 3.5 Km. of No. 24-gauge cable.

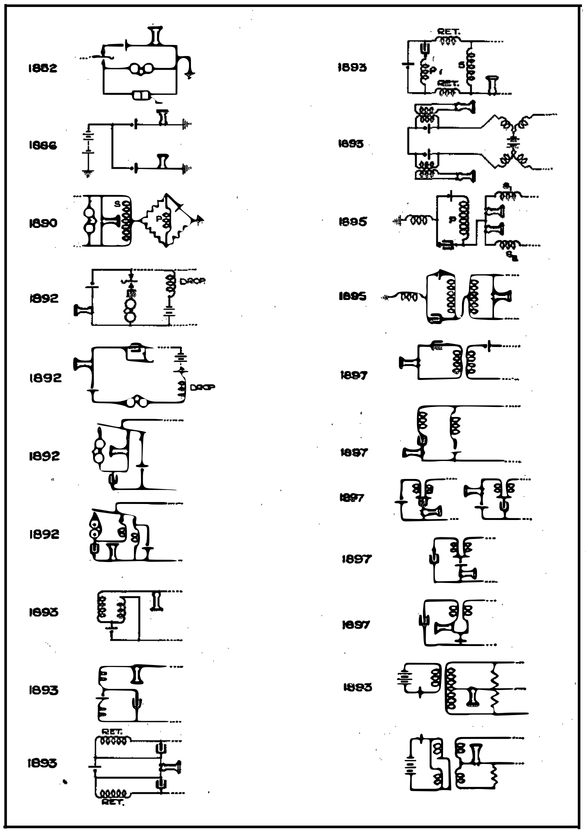


Figure 11—Historical Survey of Subscribers' Set Circuits.

Making suitable assumptions with regard to cord circuit and trunk lines, the desirable set impedance is shown in Table I in comparison with the measured impedance of various sets.

The figures given in the table illustrate the kind of difficulties encountered as a result of mutual reactions between diverse requirements. Set (a) is comparatively low in terminal impedance compared with the ideal value at 800 p.p.s. Set (b) gives a better match and has better receiving efficiency, but it also has 4-5 decibels more side tone. Sets (c), (d), and (e) have a lower impedance receiver in order to restore the receiving efficiency and side tone to more normal levels, a result which is accomplished at the expense of a disadvantageous change in the phase angle of the set impedance. On the whole it is not possible to give much weight to the set impedance, other more important factors controlling the situation.

Quite a large number of subscribers' set circuits have been proposed. The subject is too large to discuss fully in this paper, and even with a single type of circuit different combinations of induction coil and receiver windings give a great variety of results.

Factors which have had an influence on the evolution of subscribers' circuits are cost, efficiency, frequency characteristic, freedom from painful clicks in the receiver when the switch-hook is operated, side tone, and adaptability to the fitting of a dial for automatic work. This last requires that the operation of the dial shall not produce clicks or excessively high voltage discharges resulting from breaking inductive circuits.

Various circuits that have been developed are shown in Figure 11. The last of the 1897 sets has found the most widespread use and appears to meet all the requirements in a satisfactory manner. Its line terminal impedance when fitted with the usual fixed transmitter and hand receiver is given under (a) in the table.

Relation between Transmitting and Receiving Efficiency

The subscriber's set being a six-terminal network joining line, receiver and transmitter, it is possible by choice of the induction coil ratio and the apparatus impedances to increase the transmitting efficiency within certain limits at the expense of the receiving efficiency. It may be accepted as the result of experience and evolution that the relation between the transmitting and receiving efficiencies of the set shown in the circuit A, Figure 3, is adjusted to the best all-round compromise. It must be remembered, of course, that the transmitter output depends upon the battery supply current and, therefore, the performance is not fixed as in the case of the receiver. There is an advantage in keeping the transmitting efficiency high in relation to the receiving efficiency, as any increase of the latter intensifies the line noise as well as the speech, and consequently improvements in receiver efficiency lose most of their value and are preferably sacrificed (by reducing the impedance of the receiver or by altering the ratio of the induction coil) to give an increase in transmitting efficiency. The transmitting gain obtainable is, however, not at all great and is liable to be accompanied, when secured by alteration of induction coil ratio, by a disproportionate increase in side tone, and when secured by reduction of receiver impedance there are difficulties in maintaining the desired shape of the transmitting and receiving characteristics of the set.

Howling

The fact that the ordinary carbon microphone is a non-reversible mechanism possessing a considerable degree of energy amplification makes it possible under certain conditions for any disturbance in the receiver to excite the transmitter in sufficient degree to feed back energy as side tone to the receiver, and so set up a sustained howl, depending for its pitch upon the mechanical and electrical constants of the system. The mechanical coupling between the transmitter and receiver of a handset is partly through the open air, but with efficiencies at their present level the coupling is not sufficient to cause howling, and it is not likely that the efficiencies (unless it be at single resonant frequencies) will ever reach such a value that this becomes a serious consideration. The coupling between transmitter and receiver through the handle is, however, a more serious matter. It has been found that in order to prevent howling there should be no parts of the handle mechanical transmission system resonating in the range of frequencies for which the transmitter or receiver is liable to resonate. Such mechanically selective systems may occur wherever surfaces are joined, on account of the uneven and uncertain pressure between them and the reflections which arise at the discontinuities. The best way of avoiding these effects is to avoid a complex system by using as few parts as possible, mounted on a handle of material possessing such high stiffness that the necessary weights of the transmitter and receiver do not resonate with the handle as a whole, and finally any joints that are necessary should be as positive as possible.*

Any tendency to howl, even though actual howling never occurs, must cause distortion in the transmitted speech as the result of the damping coefficient being low, and the response relatively high in some regions of frequency. It is, therefore, desirable that there should be a considerable margin of safety. According to repeater practice the margin might be 7 decibels, that is, an amplifier inserted between the transmitter and receiver should not cause howling until the gain increases the side tone by 7 decibels at least. It is better, of course, to increase this margin if possible.

In illustration of the value of the moulded bakelite construction in reducing the liability of a handset to howl, figures are given below for the principal resonances of various handsets. There may be other resonances, but the principal ones are usually respectively due to the transmitter and receiver moving parts and to the elasticity of the handle loaded with the weights of the transmitter and receiver.

	Transmitter Resonance	Receiver Resonance	Handle Resonance
Moulded handset A.........	1140 p.p.s.	900 p.p.s.	2300 p.p.s.
Moulded handset B.........	1300-1400 p.p.s.	1050 p.p.s.	2200 p.p.s.
Moulded handset C.........	1700-1800 p.p.s.	800 p.p.s.	2200 p.p.s.
Ordinary handset built up with ebonite and brass....	1050 p.p.s.	850 p.p.s.	970 p.p.s.

It is at once apparent that the three moulded handsets which differ widely in construction, all have a handle resonance fairly remote from the transmitter and receiver resonances, while the older type of built-up handset has three closely similar resonances, and has in fact a considerably greater tendency to howl.

Burning, Moisture Proofing and Life

A determining factor in the microphonic life of a transmitter is often what is known as "burning"—that is, the phenomenon of dis-

*British Patents 175495, 211141, 239693.

charges in the transmitter causing crackling and hissing noises in the receiver. Burning is provoked by high resistance in the transmitter, and since increase of resistance generally occurs during life, burning is always liable to appear in service, though absent when the transmitters are new.

It may be stated in a very general way that burning prevention places one of the severest limits upon the efficiency of a transmitter built according to any given principle. Such alterations of dimensions as would increase the efficiency are nearly always such as to increase the danger of burning developing when the carbon has aged to the maximum amount. Many factors contribute to intensify the increase in resistance, which in its turn brings increase of burning, the most potent being mechanical agitation, ingress of moisture, and the passage of more or less momentary high voltage discharges, such as the inductive discharge occurring when the switch-hook is operated, or the momentary passage of ringing current when answering a call. To mitigate the results of these discharges the transmitter should preferably have a low resistance in the hanging up position in order that the actual voltage across its terminals may be reduced as much as possible.

In illustration of the ageing effects occurring in a handset transmitter, Figure 12 has been prepared showing the results obtained with a handset having parallel electrodes. The abscissae, except in the case of (c) below, represent the number of operations consisting in dropping the handset horizontally from a height of 5 cm. onto its cradle. This is naturally a severe test and exaggerates somewhat the mechanical ageing of the carbon. Three variations were adopted: (a) handsets dropped as described and connected in the electrical circuit associated with the cradle switch; (b) handsets similarly dropped but not carrying current; (c) handsets carrying current and connected to a periodically operated cradle switch but not subjected to any mechanical disturbance.

The results show very clearly how both the mechanical disturbance and electrical discharges contribute to an increase of resistance, and they also bring out the interesting result that the increase of resistance tends towards a limit.

Moisture proofing of transmitters would materially help their operation in highly humid localities. The difficulty lies in the strained condition set up in a closed elastic structure, such as a button, by the difference of pressure inside and outside, caused by the expansion of the

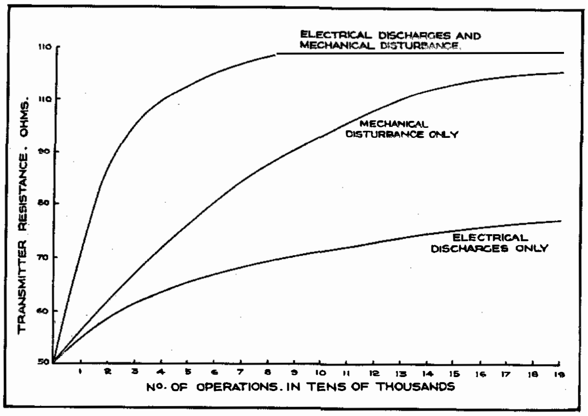


Figure 12—Variation of Transmitter Resistance During Life Test.

closed air when warmed by the evolution of heat in the granular carbon or by variation of the atmospheric pressure. In a recently developed transmitter, which will be more fully described later, protection is effected by a membrane which, if sealed, can take up the alteration in volume and pressure without causing a difference of pressure to operate upon the transmitter element.

Development of a Set

In the foregoing pages the requirements and properties desired in a modern subscriber's set have been dealt with in general and some examples have been given to show the kind of data that has to be secured. For convenience in handling the subject, the various requirements have been separated and dealt with singly. It will be realised, however, that a certain amount of compromise is necessary, and that the proper adjustment of the various factors is, on account of the interlocking of the data, a long and laborious piece of work. For example, a transmitter may be developed to the point where nearly all the required data has been obtained, when life tests, which are slow and necessarily give delayed results, may show up defects which necessitate some small change in the design, and the whole series of tests has to be reconducted, There is thus no very well defined logical order of development and testing.

Finally, when an instrument has passed all the laboratory tests satisfactorily, there are still trials and difficulties ahead. Manufacture on a large scale will present new problems and bring to light the effect upon performance of ordinary manufacturing variations in dimensions or materials. Launched in service the apparatus will have to stand undefined ill-treatment and extremes of temperature and humidity. These may show up defects not revealed by the more regularly controlled laboratory trials. Without entering into extensive details, it may be mentioned that difficulties encountered during manufacture and service have included use of materials of unsuitable temper flowing and settling under stress with loss of efficiency, evolution of products harmful to the carbon under the influence of heat developed in the button, burning

Figure 13—Modern Telephone Subscriber's Set.

arising from carbon granules becoming wedged in joints of the structure, loss of magnetism in the receiver, undesirable movements of the receiver diaphragm resulting from temperature changes, sticking of the switch-hook, corrosion or damage to finish with numerous other troubles arising from vibration or loosening of parts as a result of atmospheric variations.

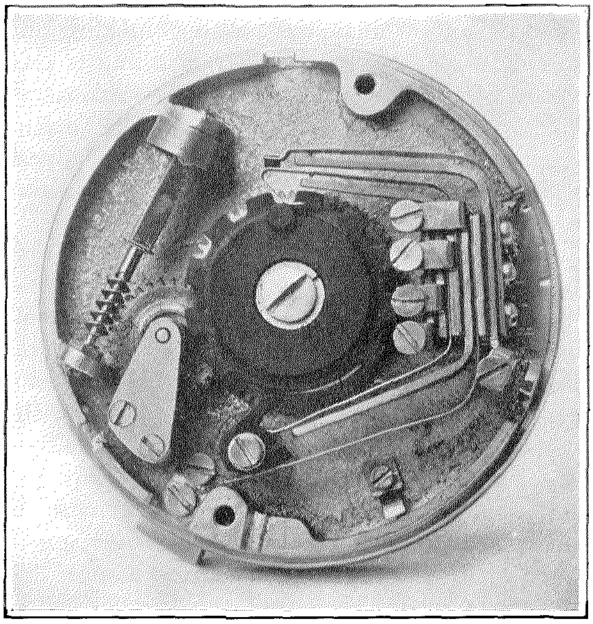


Figure 14—Dial.

Description of a Modern Set

It now only remains to describe in some detail a modern telephone subscriber's set recently developed in the laboratories of the International Telephone and Telegraph Corporation.

The set is illustrated in Figure 13. It consists of a pressed iron base or apparatus box which ordinarily mounts the ringer, condenser, and induction coil, while a cast metal upper part provides a rest for the handset and mounts the switch-hook and dial. The upper part can be mounted upon different apparatus boxes when special sets are required (intermediate-through sets, or sets with separate ringer, etc.).

Miniature apparatus as illustrated in Figure 1 permits the dimensions to be reasonably small. Attention is specially directed to the transformer type induction coil in which a laminated core, furnished with suitable air-gaps to prevent saturation, is provided.

The dial is of new design (Figure 14) specially suitable for mounting any desired spring combination, and provided with means of accurately adjusting the steel clock spring after assembly. Care has been taken to provide adequate sized finger holes while retaining the necessary margin of idle rotation of the dial to allow the exchange apparatus to operate fully before another digit is dialled.

The handset contains several new features which have been developed as a result of studying the complex requirements which have been discussed. The most casual examination of the interior arrangement (Figure 15) will reveal that the transmitter is mounted in a position never before adopted.* Earlier handsets have been either straight, with the plane of the transmitter diaphragm parallel to the receiver diaphragm plane or, by curvature of the handle or tilting of the transmitter, the transmitter diaphragm has been made to face slightly towards the mouth. In the handset now described, the transmitter has been tilted in the opposite direction, that is to say, away from the mouth. One of the reasons for this arrangement is illustrated in Figure 16, where it will be noticed that

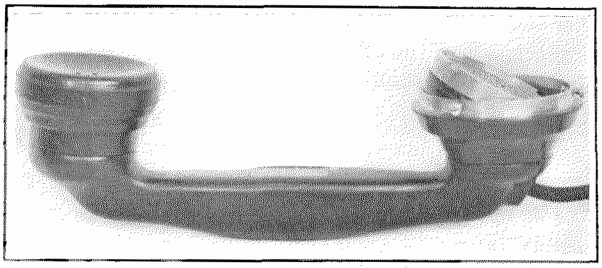


Figure 15—Interior Arrangement of Transmitter in Handset.

in ordinary use a handset is not held with the handle vertical but inclined backwards; the forward tilt of the transmitter brings it more nearly into the slightly inclined position in which a fixed transmitter is used. Similarly, in a more extreme position, with the handle lying back almost horizontal, the transmitter cannot be so placed that the carbon falls away from the diaphragm and so ceases to be driven. A handset may be used in a variety of positions of which the limits are approximately with the receiver diaphragm 70° to the vertical and face upward to a position in which the receiver diaphragm is 45° to the vertical and face downward, and it is important to avoid wide variations of efficiency over this range of positions. The forward tilt of the transmitter is designed to avoid the otherwise inevitably large variation

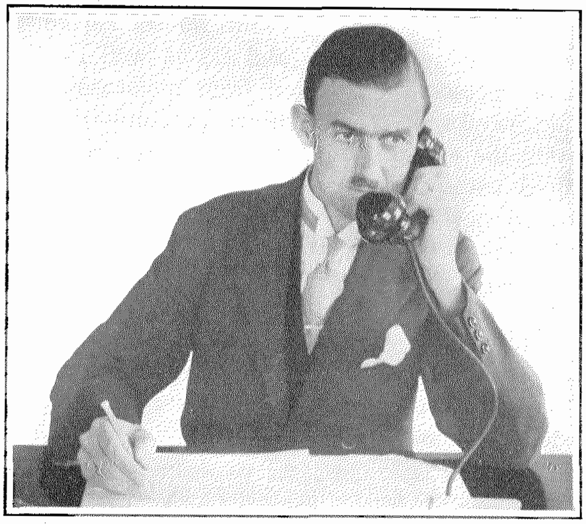


Figure 16—Handset in Ordinary Use.

of efficiency by making the position of use of the transmitter diaphragm vary round the vertical. The position in which the transmitter has lowest efficiency is, of course, that in which the carbon falls away from the diaphragm and so fails to be effectively driven; it is impossible with the forward tilted transmitter to speak into the handset with the transmitter in this position.

The transmitter button is very similar to that shown at B in Figure 8. It has already been pointed out that an inverted transmitter such as this may have a rather high resistance in the face down position, besides being exposed to moisture. The inclined arrangement of the transmitter enables freedom from excessive effects in the talking position to be secured without introducing a high resistance in the face down position and at the same time better protection from moisture is secured.

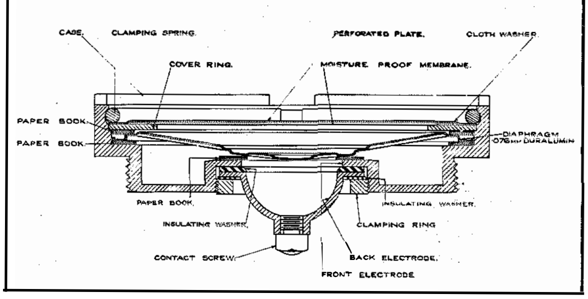


Figure 17—Transmitter Button.

* British Patent 304843

As may be seen from Figure 17 the carbon is behind the diaphragm and it, as well as the paper books, is protected from moisture by a thin membrane of specially treated material.

On the whole it has been considered that the tilted transmitter position was inherently the logical position in which to mount the transmitter and that it disposed at once of practically all the operational difficulties of a handset.

This new departure in the arrangement of a handset transmitter is at once so fundamental in its effect and so novel in itself that it seems desirable to recapitulate briefly the advantages which it secures; these are:

1. Reduced effect upon the transmitter efficiency of using the handset in various more or less extreme but usual positions.
2. Reduced variation of resistance with position throughout the range of normal use.
3. Avoidance of opening circuit momentarily when jarred in the face down position.
4. The transmitter is not in its maximum resistance position in any speaking position or when held horizontally face down, in which position it may be subjected to the destructive effects of ringing current, inductive discharge from switch-hook operation, as well as mechanical jolts.

While points 1 and 2 may be secured by the reversed button position which has already been referred to, points 3 and 4 will in general not be covered by such an arrangement.

Passing now to a consideration of the transmitter construction, it will be seen that the diaphragm is a light rigid duralumin cone without any attachment so that the moving part has an absolutely minimum weight of the order of 0.5 gram. The diaphragm is elastically supported between piles of paper rings which represent mechanically the equivalent of a condenser shunted by a resistance both in series with the inductance representing the mass of the diaphragm. This construction has the advantage of providing a stiffness which will tune with the diaphragm to a damped resonance at a fairly high frequency without making the system so stiff as to restrict the output at the lower frequencies.

The operation of the transmitter avoids the use of any moving electrode, the moving diaphragm serving merely to vary the pressure upon the carbon and so vary the resistance between the fixed electrodes. It is this circumstance that makes possible a light moving system with mechanical restraints which are designed to fulfill the mechanical requirements only, without being complicated by the necessity of conducting battery current between the capsule case and the diaphragm.

The mouthpiece is the result of much experimental work, in the course of which it was appreciated that the transmitter considered alone had such high quality characteristics that the influence of any acoustic resonance in the mouthpiece would be relatively great, *i.e.*, more distinctly appreciable than in transmitters with heavier parts possessing strong resonances of their own. It was, therefore, necessary to adjust the mouthpiece resonance very carefully in order that it might contribute adequately to volume efficiency and cause the minimum loss in articulation.

The receiver is of new construction containing a short cobalt steel magnet with welded on pole pieces. The short magnetic path enables exceptionally high efficiency to be obtained, while the high coercive force of the magnet material enables an exceptionally short magnet to be used without fear of demagnetisation occurring. The coils are wound on formed spools which may be readily replaced should any such repair become necessary.

The earcap has been carefully designed to give a good acoustical performance. It is well known that receivers practically always resonate strongly at about 800–900 p.p.s. or in practice, when placed on the ear, they resonate at about 1,100 p.p.s. This comparatively sharp resonance has been substantially reduced by dividing the air space in front of the diaphragm into two parts with a narrow connecting channel. The effect has been to increase the damping coefficient (in open air) from 100 to 250 and a gain of about 4% in articulation has been secured.*

The handset, as a whole, has received considerable attention from the point of view of securing a good appearance, although it has naturally been felt that good electrical performance was the first essential. Two points only regarding the general design need to be men-

*Articulation is measured by the proportion of meaningless syllables correctly written down by observers to whom they are transmitted over the various systems or apparatus to be compared.

tioned. First, the rigid coupling together of all parts in such a way as to prevent any part of the structure resonating at a low frequency and so producing howling,* a feature of the design which is important from the point of view of mass production because while a few samples of any type may be free from howling or may be made free from howling by adjustment of the screws securing the separate parts, a certain proportion of the mass product will inevitably howl unless the design inherently ensures that all parts are rigidly and uniformly clamped together.

The second point to be mentioned is the mouthpiece, which has been made in the so-called hygienic form, that is to say, the external surface is smooth and readily wiped. There is much that can be said about hygienic mouthpieces and opinions are very much divided, but this is chiefly due to the name which is something of an exaggeration. All mouthpieces contain openings leading to inaccessible parts, and it is always possible, if rather unlikely, that dangerous germs will be harboured in these parts. The most real danger of a mouthpiece is that of contact with the lips, a contact which in the case of a public telephone is naturally repulsive. The new mouthpiece has been designed so that the centre of the grid is nearer to the face than other adjacent parts and at such a distance that very nearly everyone can use it without danger of contact. At the same time, it can be quite easily wiped and kept clean. It is this feature of cleanliness to the eye and the avoidance of a repulsive appearance which is a justification for the use of a closed mouthpiece.

Performance

The performance of the handset that has been described cannot be adequately stated without a clear idea of the relative values for telephone transmission of loudness and freedom from distortion. The best criterion is evidently the ability to convey intelligible speech under unfavourable conditions, such as, for example, to afford communication over a long line in the presence of a certain amount of line noise. It is evident that the speech must be received with sufficient loudness to be heard above the noise, and it is also evident that the less distortion there is the more satisfactory will be the communication.

There is quite a difficulty in evaluating the two elements separately. Any new apparatus must naturally be compared with known existing standard apparatus and if the new apparatus distorts less than the old the comparison of volume efficiency is difficult and almost arbitrary. The apparatus having the greater distortion producing a good deal of noise on certain resonant vowels, it is an open question whether the better quality apparatus should be compared in loudness with the loudest sounds of the standard apparatus or with the more articulate sounds produced by less resonant sounds. Probably a fair estimate of the loudness comparison would be intermediate between these two, but this calls upon the ear to perform an integrating and averaging process which may, perhaps, be attempted in a voice-ear comparison, but which necessarily produces rather uncertain results.

Bearing these facts in mind it is believed that the volume efficiency of the new transmitter speaking an average distance from the mouthpiece may be fairly assessed at 2 decibels below that of the transmitter in circuit A when speaking close to the mouthpiece or, taking into consideration service conditions in which the fixed transmitter is spoken into from a distance of about 1.8 cm. on the average, the handset transmitter is about 3 decibels better than the fixed transmitter.

The new transmitter is relatively free from distortion compared with earlier types; suitably mounted with an open front it can in fact be used as a high quality microphone for announcing work.

A number of articulation tests have been made between two subscriber sets similar to circuit A but fitted with handsets in comparison with the same two sets containing the transmitter and receiver of circuit A. Ten observers were used for these comparisons. The following results were obtained:

*British Patent No. 211141.

Apparatus	Per cent. accurately recorded of syllables called.
Circuit A, fixed transmitter and hand receiver	66.5%
New handset	81.7%
Articulation gain with handset	15.2%

This gain in articulation represents a considerable improvement in service capability and is worth several decibels in loudness.

Other data upon the new handset has been given in this paper though it is not possible at the moment to give the complete data that is being obtained, some of it not yet being sufficiently firmly established for publication.

The following is a summary of the data available:

Transmitter

Articulation. 11% better than the transmitter standard in circuit A.

Efficiency. 2 decibels below the transmitter standard in circuit A.

Microphonic Loss. Figure 7.

Maximum breathing resistance in any position. Figure 10 Curve G.

Variation of Efficiency with position. (provisional data) Figure 9 Curve G.

Burning. Negligible.

Howling. None.

Breaking Circuit and releasing exchange apparatus. None, up to 1,000 ohm line.

Receiver

Articulation. 4% better than the receiver standard in circuit A.

Efficiency Equal to the receiver standard in circuit A.

TABLE 1.

Impedances of Subscriber Sets.

Conjugate of line terminal impedance for 3.5 km. of 24-gauge cable.	800 pps.	1,500 pps.
	600+j600	440+j440
(a) Sub. Set Figure 3	285+j218	303+j342
(b) Sub. Set as Figure 3 but higher ratio coil	520+j300	470+j465
(c) Sub. Set on Figure 3 but lower impedance receiver & 55ω transmitter.	438− j82	385+j167
(d) Sub. Set as (c) but higher ratio coil	474− j21	389+j193
(e) Sub. Set as (b) but lower impedance receiver	660− j15	445+j304

A System of Electrical Transmission of Pictures[1]

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Introduction

AMONG the many ancient and revered customs which still survive in present-day Japan, even though the origin of some of these be lost in the mists of antiquity, none is of such transcending importance, or of such vital interest to the people, as the series of impressive ceremonies lasting nearly a month, which mark the accession of a new Emperor to the Throne.

Such an event took place in November, 1928, when the present Emperor ascended the ancient throne of Japan and inaugurated the era of "Showa," or "Enlightened Peace." For the first time in history, photographs of the stirring, colorful scenes and stately processions incident to the event, and so dear to the hearts of all Japanese, were flashed from one city to another by wire, and reproduced day by day in the leading newspapers of the Empire.

The approach of the Coronation period stimulated the efforts towards a practical use of the picture transmission art to such an extent that by November, 1928, the service was fully established between Kyoto, the ancient capital, where most of the ceremonies took place, and Tokyo, the present capital; also between Tokyo and Osaka, the terminals being located in the offices of the principal newspapers in the cities mentioned.

Previous to this period, or about 1924, some tests had been made, using the early Belin and Korn systems, but these were experimental only, were not particularly successful and did not reach the practical stage. However, in July of 1928 the Department of Communications issued amended regulations permitting the electrical transmission of pictures by newspapers or news agencies having private or leased communication lines, and the commercial age of picture transmission in Japan may be said to date from this period.

The transmission system which is described in the following has been developed by the writer with the assistance of Mr. M. Kobayashi, his colleague in the Nippon Electric Company, Limited, and, therefore, is named the N. E. system. This system has been installed in the Tokyo Nichinichi Shimbun (Tokyo Daily News) and the Osaka Mainichi Shimbun (Osaka Daily News) since the beginning of picture transmission in this country and has been giving very good results in the service between Tokyo and Osaka.

The Coronation resulted in a record-breaking traffic in the transmission of pictures. During twenty-two days, which intervened between the Emperor's departure for Kyoto and his return to Tokyo, the number of pictures transmitted by the writer's system amounted to two hundred and fifty-three, of which one hundred and fifty pictures appeared in the newspapers. In point of time of transmission and reliability, exceptionally satisfactory results were obtained. For instance, on November 6, the pictures of the Imperial Procession and Imperial Carriage, which were photographed by the Picture Squad of the Coronation on the Double Bridge in Tokyo at 7:10 a.m., as the Emperor left the Palace for the station, were received in Osaka at 8 o'clock, less than an hour later, just as the Imperial Train was pulling out of Tokyo Station. These pictures, together with other events of the day, were published in Osaka on a four-page extra, first by the Osaka Mainichi at 9:30 in the morning. This, we believe, sets a record, which should adorn the first page of the history of picture transmission in Japan.

Generation of Picture Current

In the present system of picture transmission as in most of the other systems in use today, the picture to be transmitted and the receiving film are wrapped, respectively, around drums which are synchronously rotated and at the

[1] Presented before World Engineering Congress, Tokyo, Section 6, October 31, 1929.

same time driven in the direction of their respective axes. At the transmitting end, of which a brief schematic sketch is shown in Figure 1, a toothed rotating disc is used to interrupt the light emanating from a source. A pulsating light flux thus produced is projected upon the picture or the picture film.

If the cross sectional shape of a light flux emanating from a source is properly selected by adapting the shape of the screen-opening through

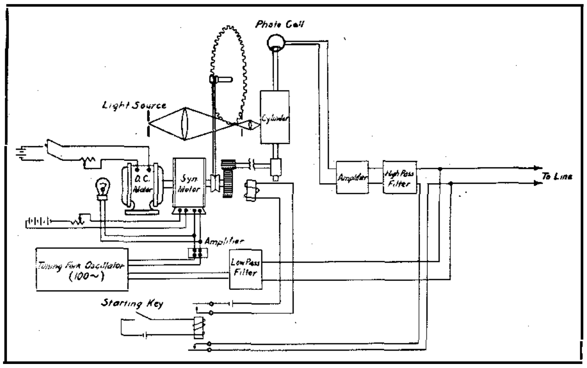

Figure 1—Sending System (Aerial).

which the flux passes, a pulsating light flux represented by equation,

$$\phi = A + A \sin \omega t \quad \ldots\ldots\ldots\ldots\ldots (1)$$

may be projected upon a picture to be transmitted by alternately interrupting the above light flux with the teeth of a rotating toothed wheel. As regards light the transmission ratio of a picture film or the reflection ratio of a picture varies with the color-tone of the picture. If this variation with respect to time is represented by function $F(t)$, then the light transmitted through a film or reflected from a picture is expressed by

$$\begin{aligned}\phi &= F(t)\, A + A \sin \omega t \\ &= AF(t) + AF(t) \sin \omega t \quad \ldots\ldots\ldots (2)\end{aligned}$$

This light acts upon the photo-electric cell.

Figure 2 shows the construction of the optical system at the sending end. The light transmitted through the film is led to the photo-electric cell by the prism, while the light reflected from the picture reaches the cell through the combination of the paraboloidal and the cylindrical mirrors. The focus of the paraboloidal mirror coincides with the light spot on the picture to be sent so that the light will directly be gathered into the cell after the reflection. The cylindrical mirrors will also lead the light into the photo-electric cell after successive reflections. Assuming that the electric current from the photo-cell varies with the intensity of light, this current may be expressed by

$$I = AKF(t) + A\,KF(t) \sin \omega t \quad \ldots\ldots (3)$$

where K is a constant. An examination of (3) shows that $AKF(t)$ is a current generated in the photo-cell by a constant light flux A being modulated in accordance with the color-tone of the picture. It is also seen that $AKF(t) \times \sin \omega t$ is a current produced by an alternating current $AK \sin \omega t$ being modulated in accordance with the color-tone of the picture. It is thus seen that from the photo-cell flows a current corresponding to the color-tone of the picture superposed by a carrier-current modulated in accordance with the color-tone of the picture. For the purpose of picture transmission either current may be used, but from considerations of transmission characteristics and the efficiency of amplification, it is better to use the carrier-current, and

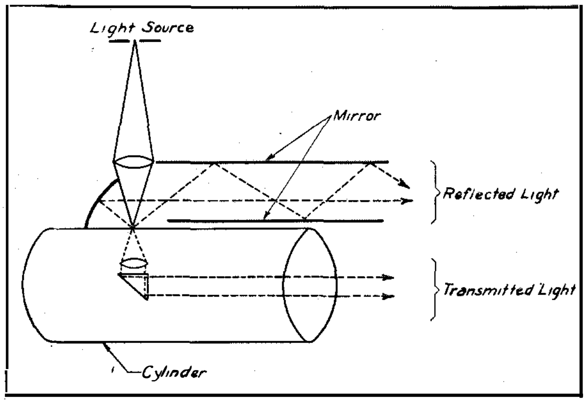

Figure 2

hence a pulsating flux is used. In order to separate these two currents a wave filter is employed and the carrier-current $AKF(t) \sin \omega t$ is taken out. If no wave filter is used and the two component currents are transmitted together, the quality of the picture received is affected greatly by blurs due to the difference in the transmission characteristics, such as the amplification ratios of the amplifier and the speeds of propagation of the two currents. Figure 6 is a picture received without the use of a filter and Figure 7 is one received when a modulated carrier-current only was transmitted by employing a filter; the difference in results being easily seen.

Synchronization

The methods for synchronous operation used in the transmission of pictures may be divided roughly into two kinds. In one, synchronizing current is used, while in the other a source of alternating current is provided separately for the sending and receiving stations, respectively, where synchronous operation is performed by carefully regulating the frequency of the alternating current. In the present system the former method has been adopted.

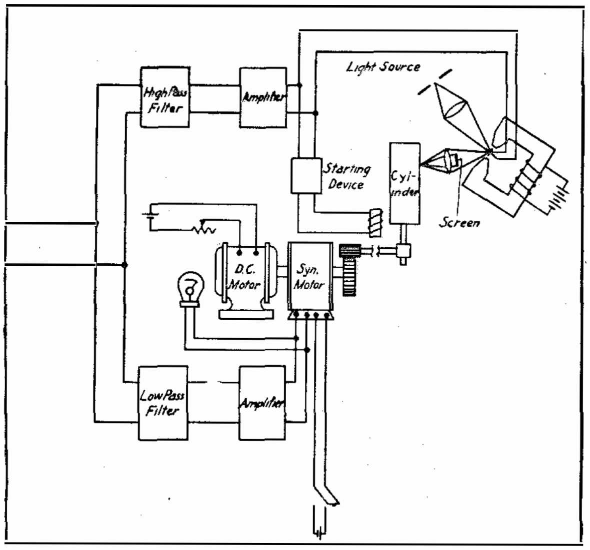

Figure 3—Receiving System (Aerial).

For the equipment to be used in connection with open wire lines an alternating synchronizing current of 100 cycles per second is generated at the transmitting terminal by a tuning fork oscillator to drive thereby the synchronous motor at this station, and at the same time this current is transmitted over the line superposed upon the picture carrier-current to the receiving terminal where, after being amplified, it is supplied to the synchronous motor. In the case of equipment to be used in connection with a telephone cable comprising telephone repeaters, transmission efficiency is low for an alternating current of 100 cycles per second. For this reason alternating currents of 350 and 450 cycles per second are generated at the transmitting terminal and these currents are transmitted superposed upon the picture carrier-current as shown in Figures 4 and 5. At both the transmitting and receiving stations the synchronous motors are operated by alternating current of 100 cycles per second taken out due to the interference of these two alternating currents.

Although it is possible to drive the picture drums by the use of synchronous motors only, D.C. motors directly coupled with synchronous motors are provided in the present system. The motor sets, respectively, for the sending and receiving stations are driven from independent batteries. The advantage of using the motors thus coupled together is that the greater part of the power required to drive the drums is supplied through the D.C. motors, the synchronous motors serving only to maintain synchronous operation. Compared with the case in which no D.C. motors are used, the current supplied to the synchronous motors in the present instance is very small, a contribution of about 10 per cent. of the total driving power being sufficient for stable operation, according to the writer's experience.

In order to detect the condition of synchronism a neon lamp is bridged across the A.C. terminals of the synchronous motor. The voltage to the lamp is the superposition of the voltage

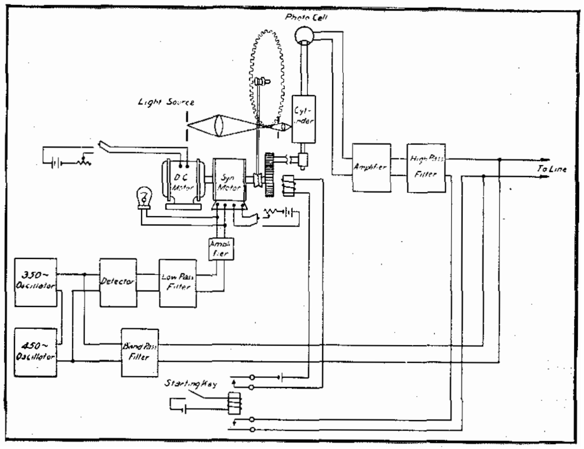

Figure 4—Sending System (Cable).

due to the synchronizing current and the induced voltage in the winding as a generator. If the motor runs in synchronism, the lamp lights steadily; while, if not, the lamp fluctuates with the frequency of slip and so synchronism can easily be detected.

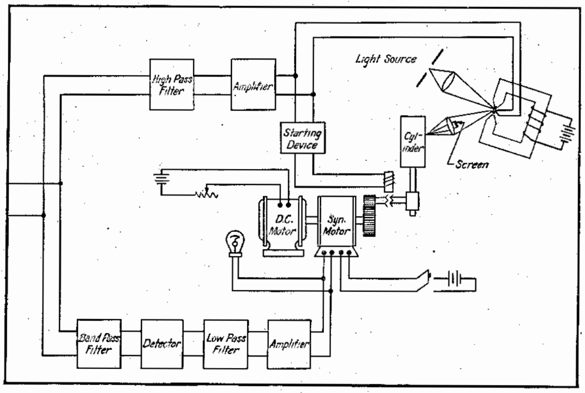

Figure 5—Receiving System (Cable).

The starting operation of the transmitting and receiving apparatus is controlled from the sending station. Accordingly, upon beginning the transmission of a picture, the drums are placed in their predetermined positions and the synchronous motor at the receiving station is started and synchronized by means of the synchronizing current from the sending station. After this, if the starting key at the sending station is closed, the sending drum starts revolving, being connected with the synchronous motor by an electrically controlled clutch. At the same time the picture carrier-current is sent to the receiving station. At the receiving station this current is amplified and detected and actuates a relay, thereby connecting the synchronous motor with the receiving drum, which then starts revolving. Thus the transmission of the picture is begun in correct framing as the sending and receiving drums are placed in proper predetermined positions. Also in this system it is not necessary to stop the motors after every picture for reloading, thus losing synchronism.

Comparing two methods of synchronous operation, the writer is of the opinion that, at least in the wired line, the use of synchronizing currents has decided advantages. Obviously, if the apparatus is run synchronously by a synchronizing current, care need be taken only of the operation of the synchronous motors at the sending and receiving stations and, as a consequence, the operation at both stations is greatly simplified. If, on the other hand, synchronous operation is performed by using a separate generator for the sending and receiving stations, respectively, it not only requires complex apparatus or mechanism, for instance, for the containers or driving mechanisms of the tuning forks in order to keep the generators to the required accuracy, but it also necessitates no small effort to maintain these apparatus or mechanisms properly and to check the two frequencies. Since these difficulties are entirely overcome by the synchronizing current method, its use appears to be of positive advantage in those systems from which it is not inherently barred by other considerations of theory, design or application.

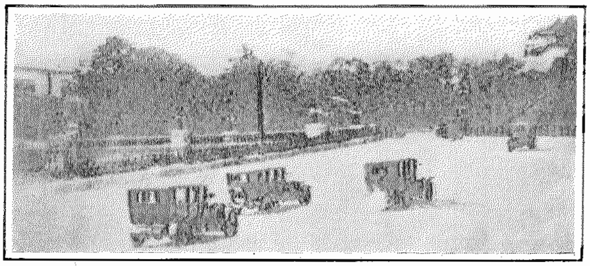

Figure 6—Picture Transmitted Without Filter.

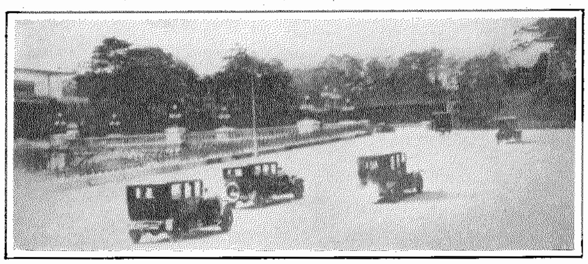

Figure 7—Picture Transmitted With Filter.

Some may argue that the sending of a synchronizing current increases current in the line, but this is of no practical disadvantage, since, according to the writer's practical experience in the use of this system, a telephone line has ample capacity for both the current used in the picture transmission and the synchronizing current, especially, if it is considered that the inducing effect of the synchronizing current with respect to other lines is, by reason of the low frequency of the synchronizing current, far less than that of the picture carrier-current. Also it may be contended that the use of a synchronizing current reduces the frequency band of the picture carrier-current and that, accordingly, in a system in which no synchronizing current is used, the frequency band of the synchronizing current may be included in that of the picture current, thereby broadening the latter band, and consequently rendering more accurate picture transmission possible. This view, however,

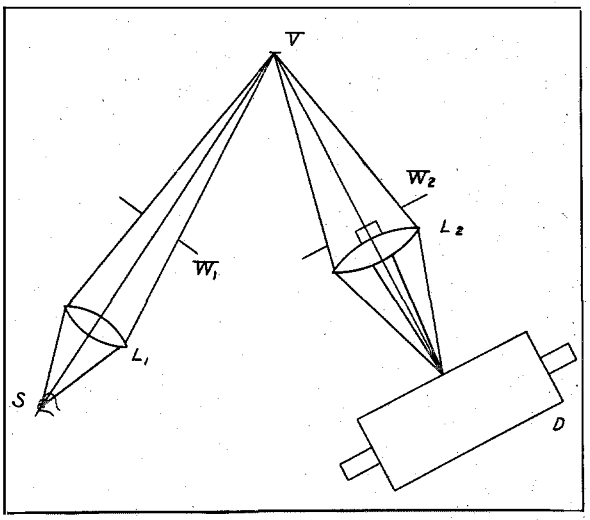

Figure 8

is not correct, for even in the systems in which no synchronizing current is used, it is customary to generate picture carrier-current by projecting a pulsating light flux produced by interrupting a constant light flux by a rotating disc upon the film or the picture to be transmitted. When a pulsating light flux is used, two currents, namely, the picture current and the carrier-current modulated in accordance with the color-tone of the picture are generated superposed upon one another, as is evident from the above discussion. If it is desired to obtain a good picture, it is necessary to eliminate the picture current by the use of a wave filter. The synchronizing current, therefore, may be superposed in the frequency band of the picture current thus eliminated without reducing the frequency band of the carrier-current. If, for instance, the frequency of the carrier-current is 1,500 cycles per second, choice may be made of the maximum frequency of the picture current, as will be described later, so that it is 750 cycles per second, this frequency being selected as the cut-off frequency in order to get the maximum speed of transmission. Then, since the frequency band below 750 cycles per second is of no use for picture transmission, if the synchronizing current is superposed in this frequency band, the quality of the picture transmitted is not affected in any way, nor is the speed of transmission reduced. For the reasons above mentioned the use of the synchronizing current has been adopted in our present system.

Receiving End

Thus, in the course of transmission, the carrier-current to transmit the color-tones of the picture is superposed upon the synchronizing current for maintaining the synchronous operation of the motor sets. These two currents, however, are separated by a wave filter at the receiving station, of which a schematic sketch is shown in Figure 3. The picture carrier-current is translated back by a vibrator type translating device into the color-tones of the picture, and the synchronizing current is used to operate the motor set at the receiving end in absolute synchronism with the corresponding set at the send-

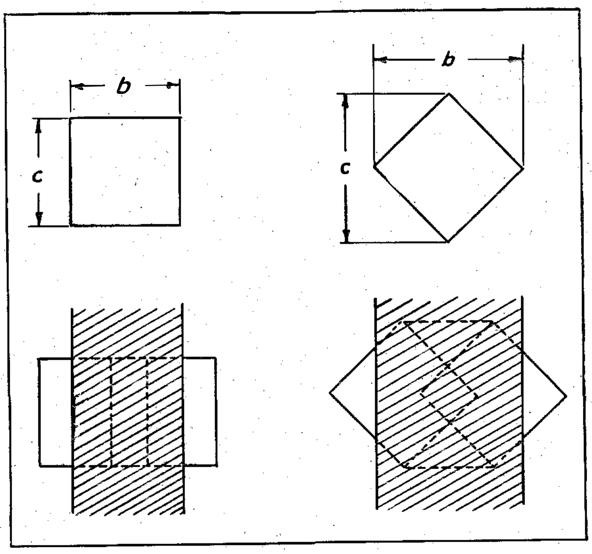

Figure 9

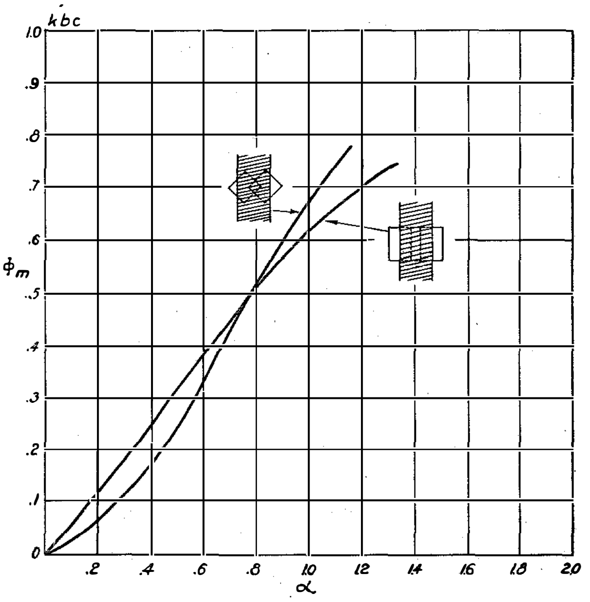

Figure 10

ing end, thus completing the picture transmission.

The main part of the translating device used in the present system consists of a combination of an electromagnetic vibrator and a screen as roughly shown by Figure 8. S is a source of light. The beams of light from this source are concentrated by lens L_1 upon mirror V of the vibrator, which is similar in construction to an ordinary electromagnetic oscillographic vibrator. W_1 is a screen placed in the path of the light. By changing the form of the opening in this screen the cross sectional shape of the light flux passing through the opening may be changed to any desired shape. Accordingly, the oscillating light reflected from the mirror V assumes a shape corresponding to the shape of opening in W_1. Now, if another screen W_2 is placed in the path of the oscillating reflected light and a part of this light is interrupted, the light passing through the second screen will bear a definite relation to the amplitude of oscillation of the light. In other words, the variations in current may be translated into variations of light. An important point regarding this translator is that various characteristics can be given to it by suitable arrangements of W_1 and W_2, and these arrangements may be roughly divided into the following two classes:

a. Central screened arrangement.
b. Side screened arrangement.

a. Central Screened Translator. We may consider two cases, for instance, in which the shape of the opening in W_1 is made a square and a parallelogram respectively, as shown in the upper part of Figure 9. When the light passing through the opening is reflected by the mirror V, it is evident that the cross sectional shape of the reflected light flux assumes the shape of the opening, if no current is flowing in V. W_2 is a band of such size that it just covers the entire reflected light flux when there is no current in V. If, however, a carrier-current flows in V, the reflected light flux oscillates to the sides as shown in the lower part of the figure, so that W_2 cannot cut off the entire light flux with the consequence that some of it passes through from both sides. The greater the amplitude of oscillation, the larger will be the amount of the light thus passed through from the sides. That is, since the greater the carrier-current, the greater will become the amount of the light, the light flux which passes through W_2 increases in amount

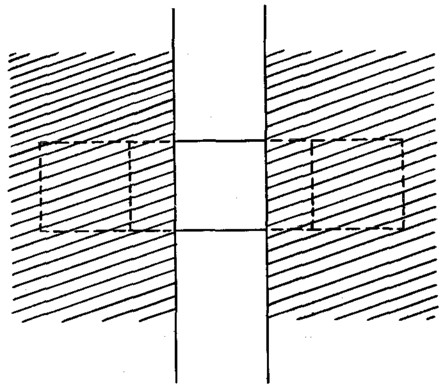

Figure 11

for the white parts of the picture at the sending station. Thus, if a negative picture is transmitted from the sending station, a positive picture is received at the receiving station, and vice versa. If the shape of W_1 is altered, the color-tone of the picture received is correspondingly changed for the same picture transmitted. The relation which obtains between the light and amplitude when the shape of W_1 is varied may be found by computation or by experiments. Figure 10 shows characteristics for two shapes of the light flux. In Figure 10, α is the ratio of amplitude of oscillation to the width (b) of the shape and the ordinate is the light flux in terms of the maximum light flux. Thus, it is seen that if a rectangular shaped light flux is used, a light flux, the amount of which varies in proportion to the amplitude of the oscillation, is obtained and that a light flux which very rapidly increases with the increase of the amplitude of the oscillation, is produced by the use of a light flux of the cross sectional shape of a parallelogram. Hence, for the same picture transmitted the picture received shows a more marked contrast of light and shade for a parallelogram-shape of light flux than for a rectangular shape.

b. Side Screened Translator. Considering the case in which the sides instead of the central portion of a light flux are screened off by changing the shape of W_2, Figure 11 may be taken for an example. If both sides of the light flux are cut off by a screen placed in the path, as shown by the figure, it is easily apparent that the greater the amplitude of oscillation of the light flux, the less will be the amount of light passing through the central opening. By choosing such a method as this a negative picture may be received by transmitting a negative picture, and a positive picture by transmitting a positive picture. The characteristics of this translator may be predetermined as mentioned above. In Figure 12 is shown the relation between the amplitude of oscillation and the light flux. This characteristic represents the case in which the size and position of the screen opening are so adjusted as to just pass the entire light flux when the amplitude of oscillation is zero. The horizontal axis represents the amplitude of oscillation in terms of the opening and the vertical axis the light flux in terms of its maximum amount. According to this characteristic the light flux is greatest when the amplitude of oscillation is least, the light value decreasing as the amplitude increases.

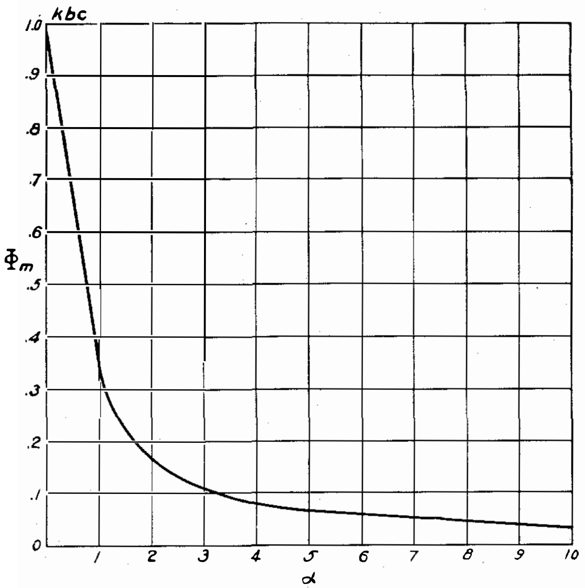

Figure 12

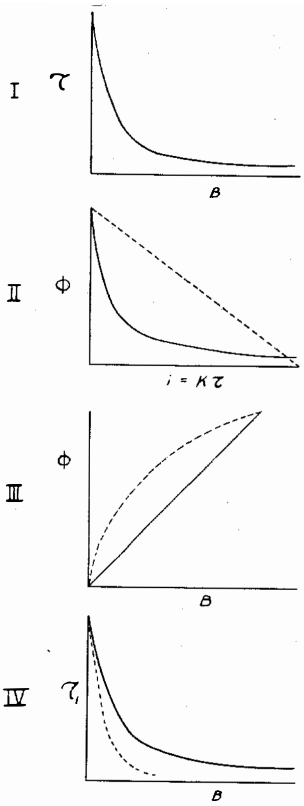

Figure 13
Negative to Negative

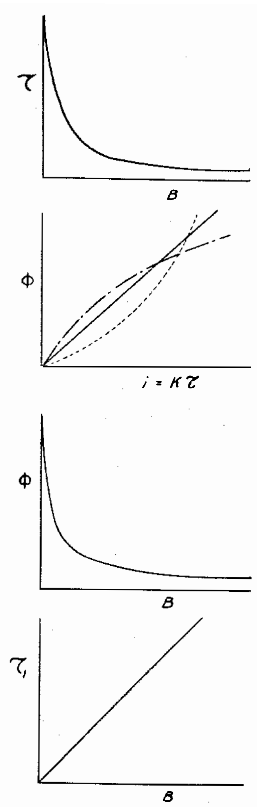

Figure 14
Negative to Positive

Translator Characteristics and Quality of Picture Transmitted

As picture transmission is nothing more or less than the reproduction, at the distant receiving station by electrical means, of pictures placed at the sending end, the characteristics of the translator should satisfy specific requirements in order to obtain ideal transmission. It is well known that a negative picture normally taken and developed has a transmission ratio which varies inversely with the light of the subject, as has been mentioned in the noted study by Hurter and Driffield, and a positive picture has a reflection ratio or a transmission ratio which varies directly with it. The characteristics required of a translator in order to obtain an ideal transmission from a normal picture at the sending end may be discussed as follows:

a. Negative to Negative Transmission. In Figure 13 curve *I* shows the characteristics of a picture at the sending station. B is the intensity of light of the subject and τ the transmission ratio of a negative film. If the negative picture has been obtained by a proper exposure, the curve assumes the shape shown by *I* as mentioned above. It was explained previously that from the sending end a current proportional to τ is sent out when such a picture is transmitted. It may, therefore, be assumed that the current at the receiving end is also proportional to τ, that is, $i = K\tau$, where i is the current at the receiving end and K a constant. If the characteristic of the translator is as shown by *II*, Figure 13, when i is translated back into light, then from *I* and *II* it is evident that the relation between the light coming out from the translator and the intensity of light of the subject will take a form shown by *III*, Figure 13. That is, since the light which is proportional to the intensity of light of the subject is projected upon the sensitized receiving film, the picture received is a complete negative as shown in *IV*, Figure 13. It is, therefore, necessary, when a negative picture is to be reproduced from a negative picture transmitted, that the translator should have a characteristic such as shown by *II*. The characteristic of the side screened translator, which utilizes the central portion of the oscillating flux produced by the carrier-current used in this system, satisfies the requirement of *II* and is sufficient for the purpose. If the translators, such as one utilizing a string galvanometer or the Kerr effect, having a characteristic shown by a dotted line in *II* is used, the negative picture received will assume a dotted line *W* and faithful reproduction cannot be obtained.

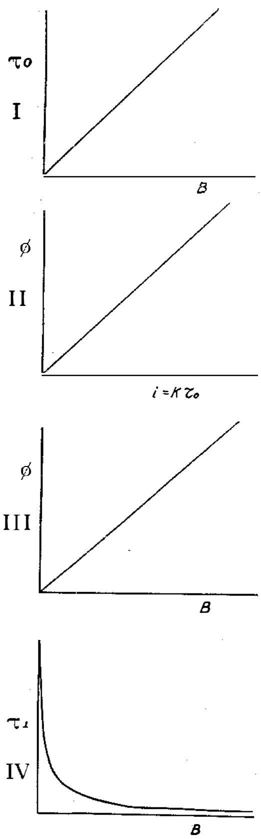

Figure 15
Positive to Negative

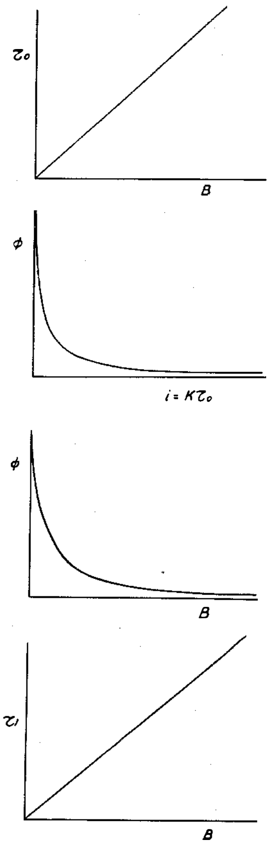

Figure 16
Positive to Positive

b. Negative to Positive Transmission. In Figure 14 *I* is the characteristic of a negative picture to be transmitted. If a translator having a characteristic shown by *II* is used, the relation between the light coming out from the translator and the intensity of light of the subject is as shown by *III*. Since the light coming out from the translator is proportional to the light which passes through the negative film at the sending station, the case is exactly like the printing of a picture, that is, the positive picture received has correct relation of light and shade as shown by *IV*. In this case it is necessary that the characteristic of the translator should assume the shape as shown by *II*, and this requirement is satisfied by the use of a central screened translator in which is cut off the rectangular central portion of an oscillating light flux produced by the carrier-current used in this system. In this case it is also possible, by suitably adjusting the shape of the screen-opening, to receive an over-exposed or under-exposed negative. When it is desired to receive

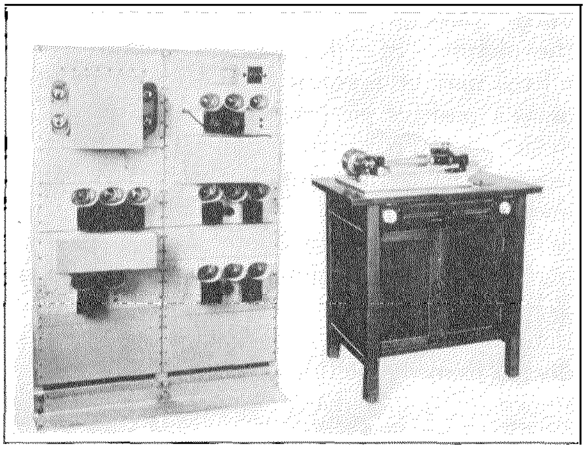

Figure 17

an over-exposed or under-exposed negative a characteristic as shown respectively by a dotted line or by a chain line in *II* may be used and in order to produce such characteristics it suffices to make the cross section of the light flux circular or parallelogram-shaped, as was previously mentioned.

c. *Positive to Negative Transmission.* Consideration may be given similarly to a case in which a good positive picture such as *I*, Figure 15, is transmitted. Since, if a translator having a characteristic as shown by *II* is used, the color-tones of the subject are transmitted unaltered to the receiving station, a good negative may be obtained by applying these to a sensitized film. That is, perfected transmission is attained if a central screened translator is used, in which the central portion of an oscillating rectangular light flux due to the carrier-current is cut off.

d. *Positive to Positive Transmission.* For this purpose a translator having a characteristic as shown by *II*, Figure 16, is required, that is, a side screened translator, in which the central portion of an oscillating light flux due to the carrier-current is cut off, should be used. In this case, also, as mentioned in the case of the negative-to-positive transmission, a translator having a straight line characteristic such as one utilizing a string galvanometer or the Kerr effect will not produce a good picture.

As discussed above, by the use of the translator of this system in which is utilized a vibrator actuated by the carrier-current, a picture may be reproduced in any desired form, positive or negative, at the receiving terminal by using a picture of either form at the transmitting terminal. The reproduction is perfect inasmuch as the original is perfect. Also over or under-exposed pictures may be perfectly transmitted by selecting the translator properly.

Reflection Method vs. Transmitted Light Method

The picture transmission systems now in commercial use employ either light reflected from the picture or transmitted light.

It may not be said that one system is better

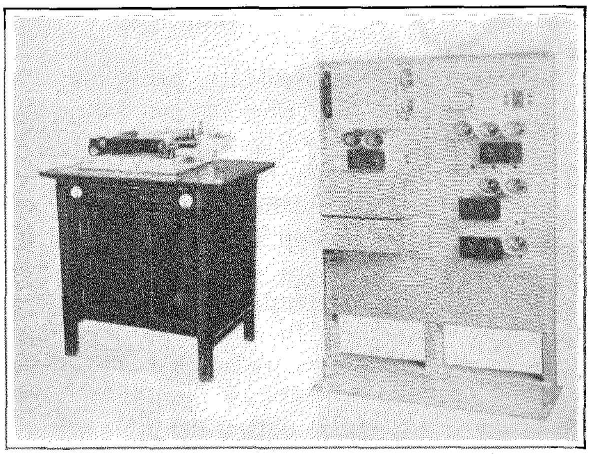

Figure 18

or more convenient than the other, since much depends on the kind of matter to be transmitted. For instance, if the picture is available in film form of proper size, the direct light method is preferable, whereas, if the positive only is available, and would otherwise require filming, the reflected light method is more convenient.

Since the limitation of the apparatus to either method would be decidedly inconvenient, it is desirable that an arrangement be employed permitting the use of either method at will. As to the quality of picture transmitted by the two methods, it may, in general, be said this depends on the quality of the original, either film or picture, at the transmitting terminal.

When it is desired to transmit a picture from its negative by transmitted light, excellent results may be obtained if the original negative is perfect. However, when a printed picture is to be transmitted by using the light reflected from it, care should be taken to get a perfect original picture by choosing the proper kind of printing paper and a suitable method of printing, depending on the nature of the negative. Some kinds of paper, such as "Velox" for example, have characteristics deviating from the Hurter and Driffield relation, and give very sharp pictures. Thus, considerable skill is required for the latter method of transmission which, however, may be employed in cases where it is desired to transmit a good picture from an unsatisfactory original negative by correcting on printing paper the lost tones in the original. Hence, in such cases the reflection method and printing paper like Velox may be used to good advantage.

In short, it is not possible to pass judgment in favor of either the reflection method or the transmission method solely from consideration of the work involved in the production of the original picture, the quality of the picture received, the degree of skill required in the transmission, etc., as the use of one or the other method alone is inevitably accompanied by some inconveniences. In the system described in this paper provisions are made at the transmitting terminal whereby a picture may be transmitted by using either the light transmitted through the film or that reflected from the picture. In either case the picture transmitted may be reproduced either as a negative or as a positive picture through the translating device at the receiving terminal, the characteristics of which are suitable both theoretically and experimentally for this purpose.

Figure 17 shows the photograph of the sending table and the amplifier and filter rack and Figure 18 those for receiving. In Figure 19 samples of pictures transmitted by light reflected from the picture or transmitted light are shown as compared to the original picture.

Speed of Transmission and Determination of Carrier Frequency

Here the writer wants to add a short discussion on the speed of transmission.

The maximum frequency comprised in a picture current is expressed by

$$f_p = \frac{n\,d\,l}{2} \quad \text{..........} \quad (4)$$

where n is the number of revolutions per second of the drum, d the number of lines per centimeter and l the length of the circumference of the drum or the length of the picture. If s is

Figure 19—(a)—Original. *(b)—By Transmitted Light.* *(c)—By Reflection.*

the width of the picture, the time required to transmit a picture l centimeters long and s centimeters wide is

$$T=\frac{s\,d}{n}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Combining these two equations and eliminating n,

$$T=\frac{sld^2}{2f_p}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

is obtained. From this it is seen that the time required in transmission varies directly as the size of the picture and the square of the number of lines per centimeter and inversely as the maximum frequency of the picture current.

If f_c denotes the frequency of the carrier-current, the frequency band of the carrier-current modulated by the color-tone of the picture lies between f_c+f_p and f_c-f_p. Of these two values, f_c+f_p must lie within the frequency limits, say f_m, in which the medium of transmission works effectively. Since, in order to obtain a picture of good quality, it is necessary to eliminate the picture current of the frequency of the color-tone, f_c-f_p; must be greater than f_p. Thus the limiting values are

$$f_c+f_p=f_m,$$

and

$$f_c-f_p=f_p\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Out of these two equations we obtain the following relations for the maximum speed of transmission

$$f_p=\frac{f_c}{2}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

and

$$f_c=\frac{2}{3}f_m\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Thus, if the maximum frequency permissible for the medium of transmission is fixed, the carrier frequency to be used to obtain maximum speed is determined by equation (9). Similarly, from equation (8) the maximum speed of transmission for a picture of a given size and of a given number of lines per centimeter is determined in accordance with the value of f_p chosen. As the present set now in practical use between Tokyo and Osaka is applied to the medium heavy loaded cable with a cut-off frequency of 2,800, we take f_m at 2,250, i. e., about 80 per cent. of the cut-off frequency, and therefore we get $f_c=1{,}500$ and $f_p=750$ to get the maximum speed transmission. As the number of lines per cm. is 80, the time required to transmit a cabinet size picture (ca. 10 cm. × 18 cm.) is about 13 minutes. The density of the line may be easily changed to 60 or 40 lines per cm. by altering the picture drum. The time required in such case is, of course, reduced proportionally to the number of lines. If the medium of transmission is open wire line and if the carrier frequency can be increased, the speed of transmission can, theoretically, be raised to the limit expressed in the equations (8) and (9). Practically, however, the speed is limited by mechanical or other considerations.

In the present system, vibrator type translator is used and so it may be feared that the natural frequency of the vibrator may cause a limit in the speed of transmission or impair the quality. Actually the natural frequency is far beyond the figure necessary for speedy and good transmission. The translator now in use has a natural frequency of 8,000 cycles and this, if necessary, can be raised to 20,000 cycles. Therefore, so far as the transmission of picture is concerned, this translator satisfies not only the necessary conditions for speed but also the requirements for quality as mentioned above.

Application to Radio

In the foregoing description the N. E. system for the electrical transmission of pictures is outlined. This system is being used in a wired system in connection with overhead lines and telephone cables, and the foregoing description is made chiefly in relation to this system. It is possible to apply this system without any modification to a carrier telephone or a radio system, as has been demonstrated by highly successful experiments. In this case it is sufficient to impress the output of this system after suitable amplification and regulation to the speech input of the wireless or carrier-current telephone equipment. In receiving, it suffices to impress the power thus transmitted, after it is detected, to the receiving device of this picture transmitting system. However, a wired system and a radio system present some inherent technical differences, and if the present system is to be applied to a radio system and worked efficiently, certain changes would naturally be introduced. For instance, whereas the writer firmly believes that it is more convenient for a wired system to transmit synchronizing current than to provide an independent oscillator at both the transmitting and receiving stations, in a radio system, in order to prevent the stepping out of synchronism of the transmitting equipments due to atmospheric disturbances, etc., separate oscillators should be provided, or else, if synchronizing current is transmitted, some device must be installed which easily restores the synchronism with respect to both time and phase when the equipments run out of step. Again, there are certain cases in which it is preferable not to transmit synchronizing current in order to effectively utilize the output of the radio transmitter. Although satisfactory solutions have been worked out regarding these details, these, in addition to the recent improvements such as gaseous discharge translator and high speed transmission, are left to a future paper, and the scope of this paper, therefore, is limited to the system in actual commercial use.

Supplement

As, during the six months following March of this year, when my main paper on the subject of picture transmission was completed, many notable incidents occurred, I wish to supplement my paper by mentioning the more important of these incidents.

In consequence of the Department of Communications' decision to open to the public the business of picture transmission between Tokyo and Osaka in 1930, and the adoption of the Nippon Electric System after a careful investigation on the part of the Department of Communications, the equipment to be used for this purpose is in process of manufacture, and probably in the spring of 1930 the first public picture transmission offices will be opened both in Tokyo and Osaka. Regulations as to charges, the kinds of pictures to be handled, etc., have not yet been published.

This government business of picture transmission between Tokyo and Osaka over the distance of 577 km. will be carried on by both aerial telephone lines, consisting of 4 mm. hard drawn copper wires and the phantoms of 4-wire medium heavy loaded repeatered circuits. For the aerial lines 6,000 cycles is adopted as the frequency of the picture carrier-current and 200 cycles as that of the synchronizing current. As for the size of pictures to be transmitted, any size up to 18 cm. x 26 cm. may be used, and the time required for transmission is approximately 6 minutes when a maximum sized picture is transmitted at the line density of 60 lines to the centimeter. Conversation may be carried on between the two terminals, while a picture is being transmitted. Repeater equipment is installed at Nagoya (situated 378 km. from Tokyo) to amplify the picture carrier-current exclusively, provision being made to by-pass both synchronizing and speech current. This repeater equipment is so designed that it may be operated as desired from either Tokyo or Osaka. Of course, a phase compensator is provided at each terminal. For the cable circuits 1,700 cycles are used as the frequency of the picture carrier-current and 300 cycles as that of the synchronizing current. The time required for transmission is approximately 20 minutes when the size of the picture transmitted is 18 cm. x 26 cm. and the line density 60 lines to the centimeter.

In the equipment described in my main paper for starting of operation and framing, the receiving drum was started from the sending terminal. But, since, according to such a method some inconvenience is introduced due to the deviation in the operating time of relays, etc., the improvement mentioned in the following has been effected.

When a picture is to be transmitted, the drums at the sending and receiving ends are caused to rotate in synchronism, but the drums are so constructed that they rotate without feeding axially until the operators engage the feeding mechanism. To accomplish proper framing, the dead angle of the sending drum is utilized. Each time this dead angle is reached, *i. e.*, once in each revolution, the carrier current is interrupted, causing a corresponding stop in the vibration of the translator at the receiving end.

The image of the vibrator mirror is projected onto a rotating disc geared in proper ratio to the receiving drum and having a projecting marker at a point corresponding to the dead angle of the receiving drum. When the sending and the receiving drums are in phase, the image from the mirror will fall upon the marker, and this condition is effected, and proper framing accomplished by gradually rotating, by hand, the stator of the synchronous motor. This starting method is also applied to the set used with cable circuits.

In the picture transmission system as developed for radio, independent synchronization is used. The tuning fork at each of the sending and receiving terminals is put into a specially designed box, which is provided with a thermostat, and maintained at a constant temperature. In order to detect the degree of coincidence of the synchronizing frequencies at both the sending and receiving stations, a certain harmonic of the synchronizing current at the sending station is transmitted as a radio wave to the receiving station where, by the use of a special harmonic producer, the thirtieth harmonic of the synchronizing frequency is taken out. This harmonic is detected after it is made to beat with the corresponding harmonic of the synchronizing current at the receiving station. When this method is used, it is possible to tune the frequencies at both stations in a few minutes. The equipment employed is the same in other respects as the one we have heretofore been using. The time required for transmission is approximately one minute for the cabinet size.

Rapid Toll, Suburban and Rural Automatic Telephone Services in Tuscany

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THE proportionate use of the telephone marks the trend of a nation's commercial and industrial prosperity. In Italy, although much leeway in telephone progress has yet to be made up, there are signs that development will now proceed more rapidly, for figures already show a hopeful annual increase of subscribers.

If this increase is to be maintained, the present policy of providing urban districts with automatic service, and abandoning the less important suburban and rural centres to an imperfect manual system, will have to be seriously reviewed.

The present telephone organisation appears to have been established upon the assumption that urban districts alone can supply the necessary volume of traffic. Around them has been built up a complex system of toll operation, necessitating a string of operators specially detailed for this particular service. Such an organisation can hardly be expected to devote much time or consideration to the needs of suburban or rural communities where low traffic and small revenue prevail.

Small urban centres and rural districts are likely to be regarded as accessories and of little interest to an operating company. They are relegated to a secondary position, and in most cases they owe their existence to an operator who has other duties—of more importance, and certainly more remunerative—to perform. Hence, with indifferent quality of service during the day, and with total cessation of service during the night, the inefficiency of the rural system becomes an accomplished fact.

Such were the conditions of suburban and rural service at the time the Società Telefonica Tirrena were called upon to undertake re-organisation in Italy. The Societa were careful not to fall into the grooves of precedent. The common arguments levelled against rural automatic telephony were carefully weighed and were found wanting. It was discovered that by judicious amalgamation and treatment of two or more districts as a homogeneous unit—to raise the total number of subscribers and consequent traffic density—a satisfactory solution of the problem would result, fully meeting technical and economical requirements.

This method has been successfully applied to the districts of Tuscany, Liguria, and Lazio. Accepted principles in telephone network formation, as exemplified by present urban service, have had to give place to a wider perspective embracing a network of urban, suburban, and rural districts, the configuration of which comprises a Main Traffic Centre to which the suburban and rural centres are subordinated, and through, or to which, the greater part of the traffic passes. As an alternative, there may be a District Centre with a group of radial junctions having direct or indirect connection with one or more of the intermediate centres, as will be explained later.

For greater zones, the same configuration is maintained by further subdivision at the various centres, the whole assuming the form of a self-contained unit with a main exchange at its centre.

Where the topography of the district is of a special character, or where special traffic conditions are encountered, certain departures from this general formation may, of course, be necessary; but in any case the maximum distance between the main centre and any of the subordinate centres will not exceed 25–30 Km.

Districts of this description will not be characterized as in the past by a series of individual exchanges, each working independently of each other, and only inter-related by a complicated toll network, necessitating the introduction of a train of manual toll operations and special staff.

The network scheme under the consideration of the Società Telefonica Tirrena aims at a single main automatic centre, serving urban, suburban, and rural districts, with a single numbering scheme, a single method of selection, and a single quality of service for all, regardless of the extent of the district or of its ultimate capacity in lines.

The district will, therefore, constitute a homogeneous switching unit, supplying a standard quality of service both to the urban mansion and to the village cottage.

More than a year and a half of research work, in collaboration with the leading manufacturing companies, has been expended in the solution of problems, now to be described, connected with the production of a system to fulfill the needs revealed by this reorganisation work.

In any particular district there can be either a flat rate call or a metered call. The first class is applicable to zones within the limits of which a subscriber can obtain an automatic call regardless of distance or duration. It thus resembles any local connection in an urban district with flat rate service.

The second class is applicable when any subscriber in one zone effects a call to another subscriber in another zone. In this case, the call is charged in accordance with the distance separating the two parties and the duration of their conversation. The two factors that determine the charge—i. e., zone and time—vary considerably.

The problem in this case is complicated by the fact that it calls for means of discriminating between districts enjoying full automatic service and those with semi-automatic service. Where full automatic service is in operation in a whole district, two subscribers, although they may not even belong to the same zone, may obtain connection by simply dialling the wanted number. But in this case, the calling subscriber's meter will not register one, but a predetermined number of calls in accordance with a rate based on the distance separating the two parties and the length of their call. This multimetering is effected by a special register, which measures the distance between the two parties, and a control clock which transmits to the register a given number of current impulses corresponding to the duration of the connection. The distance separating the subscribers is determined by the block of subscriber numbers assigned to them. A single numbering scheme throughout the district, and the subdivision of this numbering into zones, in order to obtain the required meter charge, make this possible. An area with a capacity of 9,999 subscriber numbers, for example, with a uniform numbering scheme, could be divided into three zones, as follows:

1st zone:	1,000–3,999
2nd zone:	4,000–7,999
3rd zone:	8,000–9,999

A call of the second category, for instance, would thus cause the register to meter the originating subscriber with "x" meter units for the 4, 5, 6, and 7 thousands (in case the call was for the 2nd zone), and "y" meter units for the 8 and 9 thousands (in case of the 3rd zone). The same register discriminates and translates the current impulses transmitted to it by the master clock, to determine the length of the conversation.

This method of rating is of course limited to multiples of the meter unit, and although the inflexibility of the system may be overcome in some degree—by distancing the impulses on the master clock to reduce the fee during hours of low traffic by one-half or one-third of the unit rate, for example—it remains nevertheless a fact that the system must still be based on multiple figures.

A similar scheme has been introduced into Switzerland by way of experiment, but its adoption has not been considered suitable in Italy for the following reasons:

(1) The present rates would not compare favourably with those introduced by time and zone metering, and the application of this scheme was considered too rigid for present purposes.
(2) The automatic equipment for time and zone metering is at present so expensive and complicated that its introduction is not economically justified.
(3) Automatic metering only gives a total figure reading on the meter, and consequently if a subscriber should at any time contest his telephone bill there would be no means available for proving that it is correct.

These considerations weighed in favour of the adoption of a semi-automatic service for the time being, and the semi-automatic was finally

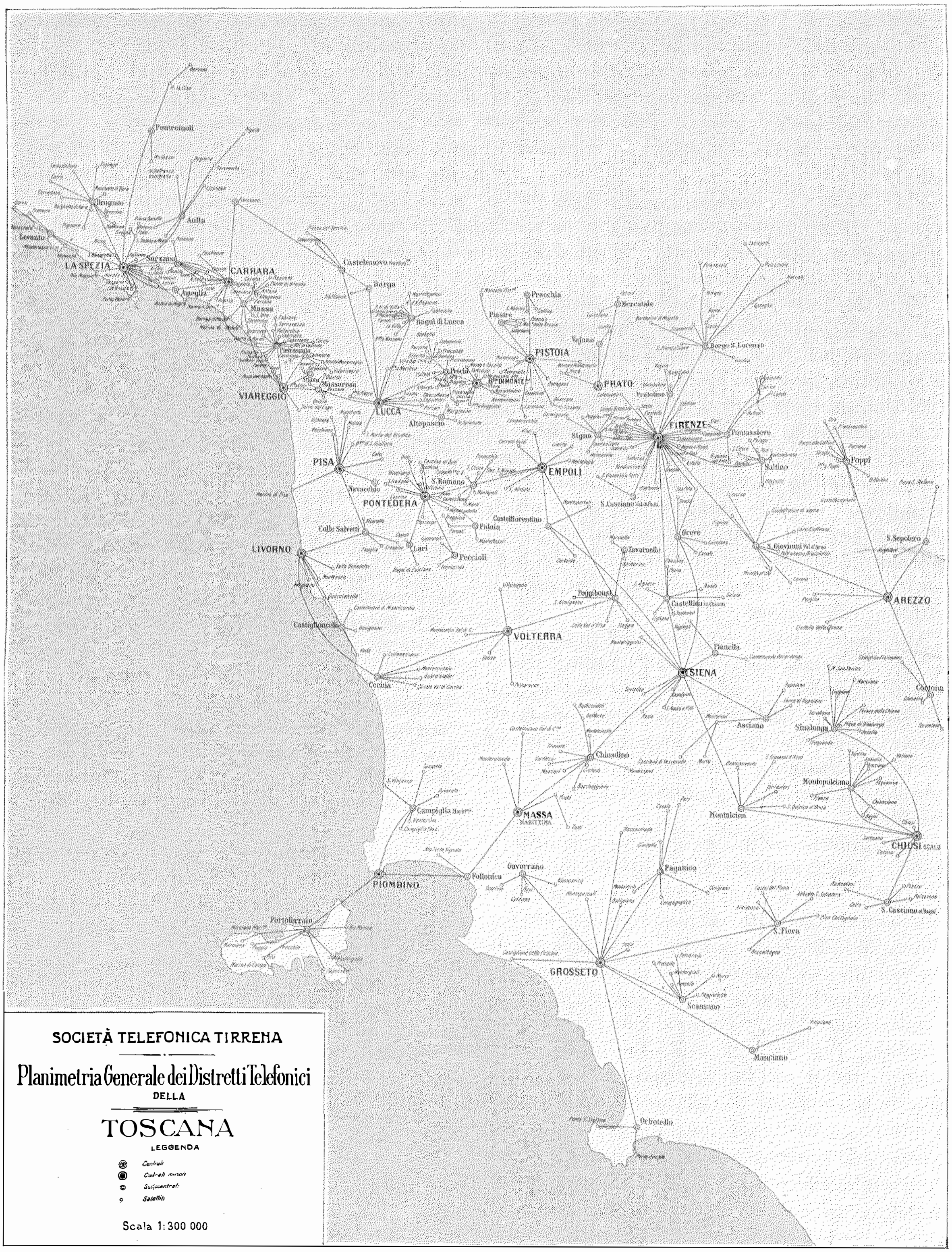

Figure 1—Tuscany Toll Lines.

decided upon for the Tuscany area. With this method, a toll manual switchboard is provided in each district centre, equipped with toll lines for inter-district traffic as well as suburban lines for automatic rural centre traffic in the same district. It is thus possible to meter all calls according to zone and time manually. Provision has been made, however, for the introduction of automatic zone and time metering whenever this may be required.

The rural automatic centres are divided into two kinds:

(a) *Automatic Rural Centres.* These centres are provided with full automatic service for connection of regular lines, automatic P.B.X. lines and satellite exchanges, for flat-rate connections to the urban system, or metered connections to the suburban system.

(b) *Rural satellites.* These satellites are provided with full automatic service for connections with urban and suburban subscribers.

The automatic equipment in the district main centre is similar to that in the service of urban districts for regular subscribers, public call stations, urban satellites and P.B.X. stations.

The main characteristic of special note, in connection with the main centre equipment, is the provision of a single manual toll switchboard for the control of meter charges to its own local traffic as well as outgoing traffic to other districts. It also provides means of supervision for the service in general.

The network is composed of a series of automatic junctions between the urban and rural centres in a given district, the districts themselves being inter-related by means of a series of toll lines over which outgoing and incoming calls are effected and metered accordingly.

The abolition of toll recording, with its inherent delay in service, which most certainly would have been introduced if the network had been planned on past conceptions, marks the first step towards a new outlook in operating methods, and has given the necessary impetus to the creation of rapid toll and rural automatic service. At the present time all toll lines in Tuscany are operated on the "rapid toll" basis, including even a few of the important trunks of inter-regional networks, by way of experiment.

Rapid Service

"Rapid service" allows for automatic control of a telephone connection over any physical or phantom circuit, repeater equipment or otherwise, which connects two automatic exchanges or an automatic exchange and a manual switchboard, irrespective of the distance separating them.

To Comm. del Pino is due not only the introduction of the "rapid service" system in Italy, but many innovations incorporated into the T.E.T.I. organisation. This aims at the extension of town automatic facilities to districts of lesser importance, by creating a single telephone system throughout the area without distinction as to the size and importance of the various centres. The pioneer work of this new and important development in automatic telephony is being undertaken in Tuscany.

Telephone Districts in Tuscany

The complete telephone network of Tuscany has been split into 19 rural districts as shown in Table I. These are interconnected by toll lines as illustrated in Figure 1. The radial networks interlinking the various minor centres with the main centre are illustrated in Figure 2, which also shows the whole network in active course of construction.

Automatic Exchanges

The automatic exchanges of the various urban and rural centres of the district were provided with initial equipments in accordance with requirements for their respective local and junction traffic. An automatic exchange may be reached by more than one district centre. The initial equipments are uniform to suit the standard sizes of the manufacturing companies, but ample provision has been made for future extension.

The Società Tirrena had adopted as standard the following methods of automatic connection and apparatus:

(a) Regular connections over a subscriber line.
(b) 1— 1 (duplex). Two-party line connections with secret service.
(c) 1— 1 (bridged). Main line set and extension set with possibility of local connections between them.

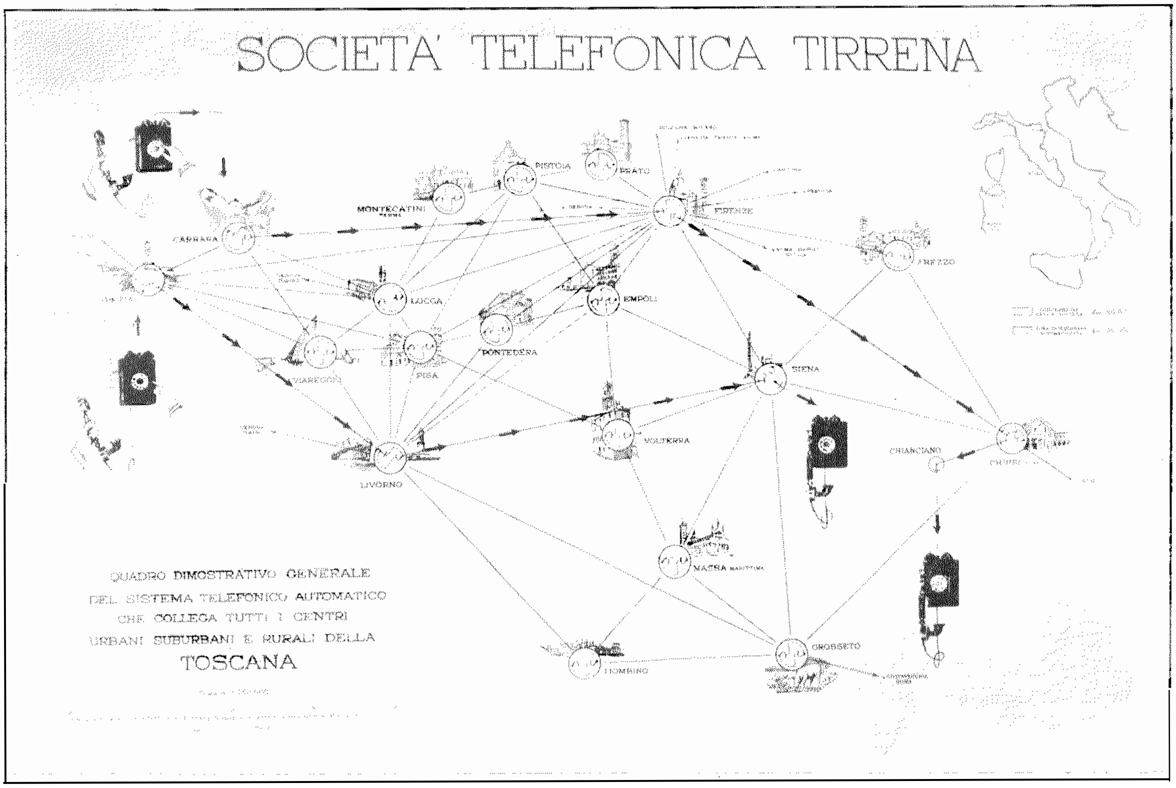

Figure 2—Radial Networks in Tuscany.

(d) 10— 1 (multiplex). Automatic P.B.X. with 10 extension lines and one junction, but without facilities for local connections between the 10 extension lines.

(e) 10— 3 Regular automatic P.B.X. for 10 extension lines and 3 junctions.

20— 4 Regular automatic P.B.X. for 20 extension lines and 4 junctions.

30— 6 Regular automatic P.B.X. for 30 extension lines and 6 junctions.

50—10 Regular automatic P.B.X. for 50 extension lines and 10 junctions.

100—20 Regular automatic P.B.X. for 100 extension lines and 20 junctions.

For communities of over 100 subscribers, regular exchange equipments are provided.

Exchange Initial Equipments

In order to appreciate fully the importance of the undertaking, Table I, showing initial equipments of the various exchanges, may be examined.

District and District Number	Exchange number of lines.	Toll Exchange number of lines.	Number of Rural Centres.	Number of Satellite Exchanges	Total initial capacity of	
					Rural Centres Lines.	Satellite Exchanges Lines
1. Firenze	9,000	100	3	22	253	732
2. Prato	1,000	32	2	4	77	8
3. Pistoia	800	24	1	16	12	206
4. Montecatini	700	16	1	19	330	195
5. Lucca	1,100	24	3	24	462	339
6. Pisa	1,300	32	1	10	23	166
7. Livorno	3,000	32	2	15	78	183
8. Viareggio	800	24	2	13	700	437
9. Piombino	330	12	1	14	55	320
10. Volterra	120	16	1	15	55	186
11. Massa Marit.	120	8	2	12	110	94
12. Grosseto	330	24	3	11	101	228
13. Pontedera	330	24	3	24	111	379
14. Empoli	550	24	3	26	165	394
15. Siena	1,000	24	7	28	331	383
16. Chiusi Scalo	330	16	4	17	188	292
17. Arezzo	550	24	2	24	165	233
18. Carrara	800	24	3	21	990	648
19. Spezia	1,400	32	3	25	165	369
Total	23,560	512	47	340	4,371	5,792

Multi-Control

The control of an exchange from various centre exchanges merits special attention.

(a) Where the selection of an automatic exchange is under the control of one or more districts, it follows that the numbering in each district must be the same. If, for example, the automatic exchange is provided for four digit selection, these four figures must be exactly the same as the last four digits used by centres with five or six digit dialling.

(b) When the satellite is controlled from more than one automatic centre, which although infrequent is not impossible, the numbering of the satellite lines must be identical with that in each of the centres from which they are controlled for selecting purposes.

(c) Multilateral control must afford a means of connecting, for example, an automatic exchange either to a district with flat-rate service, or to a district with multi-metering service, so that the control gives to the system a greater measure of flexibility than in the case of a manual system.

Toll Switchboards

The toll switchboards may be considered as one of the most important features of the installation, as it is through them that control is kept on the payment of calls passing between one district centre and a suburban centre.

In their initial stages, the toll positions have been provided with the quantities as given in the above total, but they are arranged to extend to three times their present size. Each operator's load is not limited to the traffic originating from a certain number of toll or rural lines, as in the past, because as will be explained later, the traffic on reaching the toll board is evenly distributed over all the operators with a view to avoiding the necessity of a separate recording service.

Concentration between the various positions is foreseen, however, and care is taken to adjust the number of operators to the requirements of the traffic during the different hours of the day. Besides this arrangement there is a further method of concentration which, from many points of view, may be considered of more importance. This is in connection with the rapid automatic toll service between the toll switchboards of the various districts. If, for example, the district of Viareggio should be found to handle an insignificant toll traffic during winter months, this traffic could be switched by means of the Viareggio-Pisa toll lines to the Pisa toll switchboard, from whence it may be temporarily handled. A similar method of concentration is provided for other districts.

Dialling from the toll switchboard to automatic exchanges over rural or toll lines is usually effected by means of alternating current (A.C.) impulses in order to make use of the phantom circuits, and to ensure correct connection between distant centres.

In some cases, and especially where short lines are in existence, direct current (D.C.) impulse dialling over phantom circuits is in use, but this system is not generally favoured.

The face equipment of a district toll switchboard does not present much similarity to that of the generally accepted equipment, inasmuch as the former must include equipment possessing the following characteristics:

(a) Toll lines equipped for long distance A.C. dialling over physical or phantom circuits with both-way service for the control of metered toll connections between the various district centres.

(b) Rural lines equipped for long distance A.C. dialling over physical or phantom circuits with both-way service for the control of metered rural calls with rural centres of the district.

(c) Outgoing urban junctions for D.C. dialling for control of the urban traffic of the district centre.

(d) Regular toll lines for both-way service with jack, relay, and lamp equipment for lines not appertaining to the rapid service.

(e) Regular incoming recording lines from the automatic exchanges.

The corresponding equipments at the district automatic exchange end are as follows:

(f) Regular lines for subscribers and public call stations with the flate-rate service.

(g) Junctions to rural exchanges or urban satellites working on the flat-rate service.

(h) Incoming toll lines for inter-district connections as explained under (a).

(i) Rural lines from the toll switchboard for connections from other districts to rural centres.

(j) Urban junctions incoming from toll switchboard, as (c).

(k) Recording lines outgoing to toll switchboard.

Inter-District Trunk Routing

Two methods of routing are provided for rapid toll calls between the districts.

(a) *Direct inter-district dialling.* When district "A" is directly connected to district "B," the toll operator at "A" can dial over a special line the "B" automatic exchange without the introduction of any intermediary switching point. This arrangement provides very rapid service between the districts. The method is only applicable to very long lines where the traffic density is sufficiently important to compensate the high cost, or on the other hand, on short lines, as for example, between two neighbouring districts.

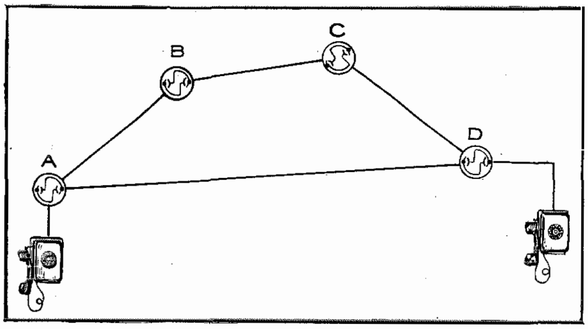

Figure 3—Indirect Inter-district Dialling.

(b) *Indirect inter-district dialling.* Where two centres are a great distance from one another and where, moreover, the amount of traffic is insufficient to justify the establishment of direct junctions between them, or where the existing direct junctions are all busy, a call can be effected by indirect or tandem operation. In order to make this point clear, reference should be made to Figure 3, which illustrates four districts, A, B, C and D, arranged in circular formation. From this it will be clear that calls between A and C and B and D cannot be effected without passing by B and C, respectively, and that when all the direct junctions between A and D are engaged, a further call between the two centres A and D cannot be made without passing through B and C.

To give effect to this method of routing a call, it is thus necessary that all groups of inter-district trunks should be accessible to the toll position for direct calling, and to selective equipment in the automatic exchange centres for indirect calling, as follows:

When the toll operator of A wishes to call the automatic exchange B, she plugs in on the associated trunk group AB and dials the desired number. Now, a certain number of outlets in the selecting field at B are connected to the trunk group BC, which can be reached by dialling a predetermined number of one or more digits.

For example, the A centre may have access to the group of trunks BC over the xy level, after selection of which, a further selection will extend the call to a level reserved to the CD group of trunks in the following exchange, and thus the D exchange will be reached. By this means, the problem of tandem operation is completely solved, and offers an almost unlimited method of inter-district connection. For practical purposes, however, it is not advisable to go beyond two or three successive stages of tandem selection.

Tandem trunking of inter-district calls brings with it a certain complication in switching equipment which is counterbalanced by greater trunk efficiency than exists with direct trunk working. Direct trunking, as before stated, is now almost exclusively limited to long distance lines with heavy traffic, or to short lines between neighbouring districts.

Method of Operation

The above explanation will now make clear the method of operation which is being employed for district service.

(a) *Automatic exchange of the district centre.* A local subscriber of the district centre who wishes to call another local subscriber or an urban satellite subscriber, dials the relevant number in the usual manner. If he should desire a toll connection, or a rural exchange subscriber, he dials the digits "01" and is thereby connected to the operator, to whom he communicates the wanted subscriber's number.

(b) *Urban satellite exchange of the district centre.* The method of operation of the subscribers connected to this satellite is the same as that of the district centre without any abridgement of the service facilities offered.

(c) *Rural centres.* Upon the subscriber making a call, his line is automatically connected to a connecting circuit. A "dialling tone" is received by the calling subscriber, who thereupon dials the digits of the wanted number. These digits are always dialled in full, even when the call has to be handled by the suburban operator. If the wanted party pertains to a flat-rate zone, the call goes through automatically. On the other hand, if the call should be destined for another zone, it is routed by the suburban operator, who makes the required connection and meters it according to the charge.

(d) *Rural centre satellite.* Upon the subscriber making a call, his line becomes automatically connected to a junction to the rural exchange. The subscriber receives the dialling tone, or if the junctions to the exchange are "busy," he receives the "busy tone." If the number dialled by the calling subscriber is that of another subscriber of the same satellite, the line of the calling party first becomes connected to a local junction circuit, but upon the called subscriber answering, the junction line is freed. The same methods are applied to a local call in a rural centre.

(e) *Toll exchange.* The toll operator desirous of calling a district centre subscriber or district centre satellite subscriber plugs in on one of the urban junctions. Upon receiving the "dialling tone," he dials the wanted party's number. When the call has been established, he can recall the subscriber by depressing the calling key. If the subscriber is busy, the operator has facilities for listening-in and can advise him of the toll call and afterwards break down the local connection.

To call a subscriber connected to a rural exchange, the operator plugs into a free junction connected to the exchange. After receiving the "dialling tone" the operator dials the wanted number. If the subscriber is busy, the operator can listen-in on the local call and, if necessary, break it down. On the other hand, if the line is busy on a toll call, the operator receives a busy tone signal and in this case the breakdown of the connection is not possible. The same procedure is followed in connection with the establishment of calls to rural satellite subscribers.

Regarding calls for subscribers outside of the district, it has already been explained how they are effected by direct and indirect trunking.

New Principles in Automatic Telephony

It is no exaggeration to say that the introduction of automatic telephone service in Tuscany has created altogether new principles in the field of automatic switching on a large scale. To demonstrate this, it will suffice to glance at the conditions which prevailed before the work of the Società Tirrena had been started.

(a) *Single numbering in each district for automatic control of all connections.* The single numbering scheme replaces the numerous independent numbering allotments which were heretofore assigned to each large or small centre, and eliminates the necessity for distinguishing by a special prefix these centres one from another.

Today, the only prefixes retained are those in connection with the various districts, which total in all 19 for Tuscany, 5 for Liguria, and 6 for Lazio, giving a grand total of 30 prefixes for the whole of the Fourth Zone, in place of the thousands of prefixes which before obtained. As an illustration, consider the subscriber number "85728 Firenze." This is the only subscriber in the whole district with such a number, whether he pertains to the city of S. Giovanna or Vallemoso, and no further identification is required of him other than the name of the district "Firenze," which distinguishes him from subscribers having the same number in other districts.

A single numbering scheme throughout the district affords a single method of selection, and also eliminates all special intermediary services. With the absolute precision of automatic switching, it is possible to obtain not only the wanted subscriber's line, but discrimination between non-metered and metered calls, trunk offering and breakdown for toll calls, listening-in and any other service requirements.

The only special service retained for the time being is the recording service. This is for economic reasons, as in view of the high cost of long distance telephone lines, it has not been found possible to supply a sufficient number of direct trunk routes necessary to obtain even a normal waiting time during hours of maximum traffic. Thus, if the scheme without recording service had been followed, it would have given rise to inconvenience, such as a subscriber making repeated efforts for his call while another subscriber, seizing the junction just at the time it became free, would obtain unjustified precedence.

To avoid dissatisfaction in this connection the recording service was retained for the present time, but it is already being planned to substitute switching equipment to handle automatically these calls in their order of sequence. This method of working will be put into force as soon as it is decided to adopt full automatic operation throughout the network.

The recording service itself, however, has undergone radical changes, inasmuch as both the recording and toll lines are now supplied with calling and busy lamps and are multipled over all the operators positions, so that upon the appearance of a call the first free operator can reply and handle the connection direct from his position. In this manner, the waiting time is practically reduced to nil in all cases where a free trunk is available, and is reduced to a minimum in the case where all trunks are momentarily found busy.

(b) *Metering arrangements.* As previously mentioned, the manual method of registering calls has been retained in Tuscany instead of automatic time-zone metering, since the latter does not provide the operating company with adequate safeguards against complaints from subscribers. This consideration has affected the design of the automatic register which, however, arranges for the discrimination between local zone calls, where no metering is necessary, and for calls where manual metering is required.

(c) *Register functions.* Other features of the automatic register are as follows:

(1) *Register as translator.* The register receives a train of impulses and modifies or translates them into other trains of impulses in accordance with prearrangement.

(2) *Register as selector.* The register receives the impulses dialled, and sets up the train of switches for the selection of the wanted party's number.

(3) *Register as a by-pass.* Where a call does not engage the whole train of local switches in one exchange, the register releases those that are not required so as to reduce the switch holding time.

(4) *Register as director.* This is an arrangement whereby the register is enabled to augment or absorb certain of the impulses received from the dial so as to add or eliminate certain stages of switching with a view to the selection of the most economical routing of the call.

(5) *Register as interceptor.* An arrangement which restricts the establishment of certain connections whenever the caller is not authorized to make such calls, in which case the said call is diverted to an operator's position, who advises him accordingly, or he is otherwise advised by a special tone.

(d) The inter-district service has already been described, as well as:

(e) The multi-control of the automatic centres. These two fundamental features of the T.E.T.I. system contribute more than anything else to the great flexibility and economy of the telephone network.

(f) The various tones for dialling, busy condition, etc., are considered to be of great importance by the Società Telefonica Tirrena, particularly the discriminating ring used in connection with toll calls. It is required that the discriminating ring operate with greater frequency in order that the subscriber will answer this type of call more promptly, with consequent speeding up of the service.

(g) The trunk offering and breakdown of local connections in favour of toll calls are methods of operation already established in Italy, and it is assumed that, with the increased development of the toll network, the necessity for the breakdown feature will eventually disappear.

(h) Distant metering control with consequent engagement of junctions purely for this control is necessary for the economical utilisation of the lines during the initial period of the service.

(i) Alternating current dialling over rural and toll lines was adopted, not only to make use of the phantom circuits, but because such a method possesses a factor of security on long distance lines, far in advance of a system using direct current.

(j) The operating personnel attached to the automatic installation of the T.E.T.I. system is very small, and generally confined to the district centre exchange. They are required primarily in connection with the operation and maintenance of the manual switchboard in each of the district centres. The various automatic exchanges in the district are only visited periodically for routine maintenance, and in exceptional cases where an alarm transmitted from the rural exchange to the control desk in the centre exchange indicates need for such a visit.

(k) The charging of the batteries in the automatic centres is effected automatically, and can be regulated from the district centre over junction lines.

(1) Faults developing in the rural centres are also automatically signalled in the district centre exchange, by the closure of alarm circuits over junction lines.

(m) Faulty equipment is automatically cut out of service, as well as calls originating over defective subscriber lines.

(n) The supervisory positions of the toll switchboard in the district exchanges have been arranged to provide for various special service calls such as information and complaints, so that any subscriber in the district, irrespective of the exchange to which he pertains, has a centralised service at his disposal.

(o) As has already been explained, the transfer of toll traffic from one district switchboard to another is possible in order to utilise the services of the operating personnel to the fullest extent.

(p) Other fundamental features of the T.E. T.I. system are as follows:

(q) The called subscriber must have facility for freeing himself from a connection.

(r) It must be possible to send ringing current through an engaged train of switches without breaking down the connection, so that in the case of a toll call, ringing may be repeated freely at the discretion of the operator.

(s) The system must operate satisfactorily over a subscriber's loop with a maximum resistance of 800 ohms, including the subscriber set. The minimum insulation resistance of the subscriber lines and junctions may fall to between 10,000 to 20,000 ohms, measured between the two wires of the line, and between each wire and earth, without endangering the satisfactory operation of the system.

(t) The number of permissible faults in each automatic exchange must not exceed 5 per 1,000 for every 5,000 calls sent in.

(u) The automatic exchange equipment must be housed in iron or glass casings for protection purposes.

Conclusion

The installation projected by the Società Tirrena aims at the constitution of a complete network of automatic switching centres in Tuscany with nineteen manual switchboards for routing the calls between districts and registration of calls on a fee basis. The same principles have also been adopted in the conversion of the Liguria and Lazio areas.

Voice Frequency Dialling

Field Trial and Demonstration in Italy of Four Frequency Toll Signalling System

AN interesting demonstration of voice frequency dialling was given at Rome on October 30th, 1929, when dialling into the Florence automatic area 280 Km. away was carried out from a number of subscribers' sets in Rome, and also from an operator's position at Rome. The new four frequency toll signalling system developed by the International Telephone and Telegraph Laboratories was used, and the demonstration was attended by the following officials:

His Excellency Admiral Ciano, Minister of Communication in the Fascist Government; Professor Commandante Pession, Director General of Posts and Telegraphs; Professor Di Pirro, Technical Director of Posts and Telegraphs; Commandante Delpino, Director General of the Società Telefonica Tirrena; Engineer Zanni, Technical Director of the Società Telefonica Tirrena.

The trial was carried out in conjunction with the Società Telefonica Tirrena, who are the concessionaires of the Fourth Zone. A special set-up was arranged by means of which the normal subscriber's set of each of the above officials was used to dial directly not only the subscribers of Florence but also those of Livorno, Siena, Empoli, Pontedera, Pistoia and other centres of Tuscany (using the Società Telefonica Tirrena's "celere" switching system). As no difficulties were experienced, either during the actual demonstration or during the preliminary trials, the demonstration may be regarded as a very satisfactory test of the possibility of dialling by means of the four frequency system.

In the regular course of operation the equipment in question provides for service from an operator's position and for automatic calling and clearing signals and for supervision by the Rome operator of the called subscriber in Florence. The transmission of impulses by means of voice frequency equipment has, of course, been carried out in the past, but this installation is believed to be the first voice frequency dialling equipment designed to give complete signalling facilities that has been set up in Europe on a commercial basis.

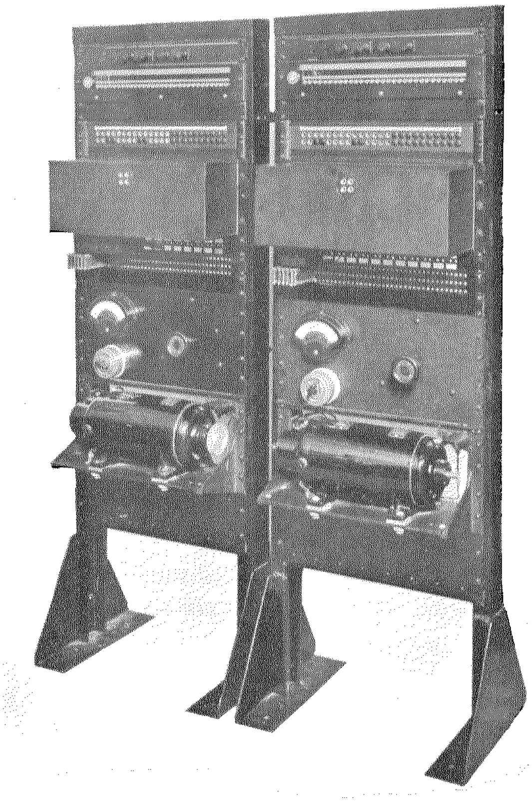

Figure 1—Equipment Used for the Rome-Florence Demonstration of Voice Frequency Dialling.

The four frequency system which has been used is a new voice frequency system, the outstanding feature of which is that it uses signalling currents of four frequency within the voice range. The large number of different frequency combinations obtainable afford a greater degree of flexibility in the matter of producing complex supervisory signals.

Further, the use of signals consisting of more than one frequency makes it easy to avoid false

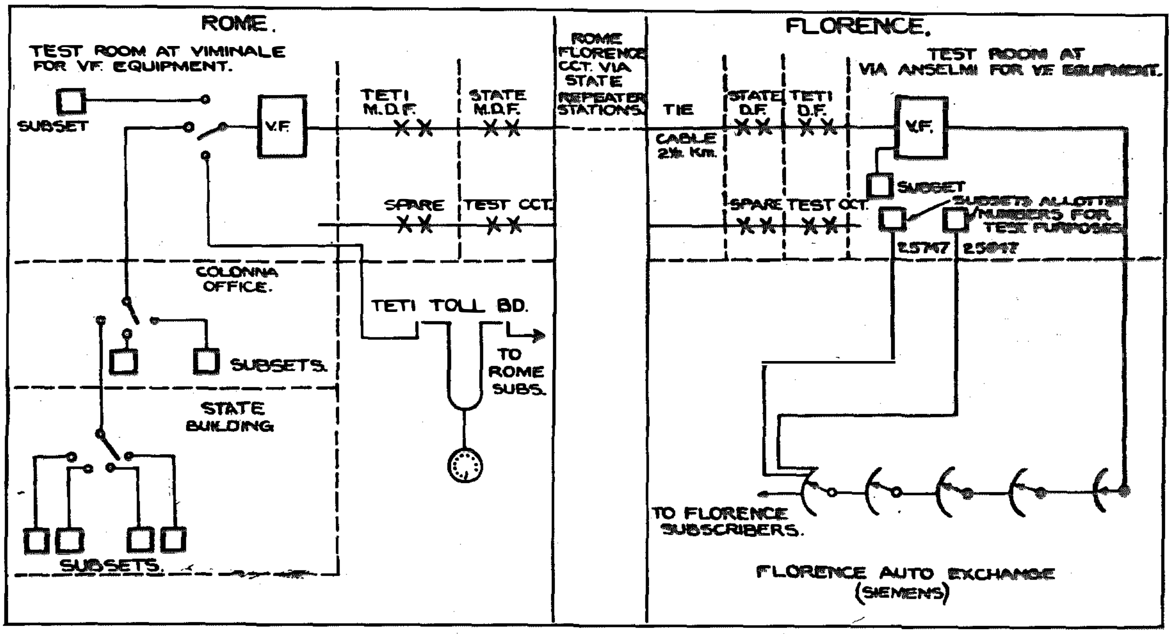

Figure 2—Circuit Layout of Field Demonstration and Trial in Italy of the Four Frequency Toll Dialling System.

operation of the signalling circuits by voice currents. This is one of the outstanding difficulties of automatic working on toll lines by voice frequency methods, and the four frequency solution, by providing in a single step both adequate and flexible signalling facilities and freedom from voice operation, may be considered an important advance in technical methods. In this system tuned voice frequency relays of a simple design are used to detect the voice frequency currents, and only a 24-volt battery is required. The system has been developed as part of a general study which is being made by the International Telephone and Telegraph Laboratories with a view to the provision of more efficient toll switching systems.

The accompanying reproduction (Figure 1) shows the equipment which was used for the Rome-Florence demonstration. One of the small racks shown was installed at Florence and the other at Rome. Each rack carries a voice frequency generator with its control circuits, together with a small panel which mounts the line equipment, and which is seen near the top of the rack. This line equipment consists of a group of voice frequency relays and direct current relays. As an instance of the reliability of the voice frequency relays it may be recorded that after a very severe journey from London, which actually smashed some of the screw heads holding the panels to the racks, and damaged all the direct current relays, it was still unnecessary to adjust the voice frequency relays or even to take off their covers.

The circuit layout of the trial and demonstration is shown in Figure 2. A standard two-wire medium heavy loaded circuit was used, this being one of the circuits in the new Rome-Florence cable installed by the Società Italiana Reti Telefoniche Interurbane, and opened on October 28th, 1929. Normally the line terminated at an operator's position, but it could also be switched through to a number of Rome subscribers' sets, so that a particular Rome subscriber could be made, in effect, a Florence subscriber.

The method of working used by the toll operator was as follows. To obtain a subscriber in the Florence district she plugged her cord into the line, and, without waiting, dialled the desired number. On receipt of the Florence subscriber's reply the operator's supervisory lamp was extinguished. When the Florence subscriber hung up, the supervisory lamp was lit again, and the operator then pulled out her plug and the circuit was restored to normal. It will be seen that the toll operator was thus able to treat the toll line in the same way as she treats a local junction leading to local automatic equipment.

When the Florence subscriber was busy the operator received a busy tone. The voice frequency circuits were arranged to provide the toll operator with facilities for offering the call to the busy subscriber and to provide busy flash, but the automatic equipment for Florence did not permit this, and consequently these facilities were not used. For a permanent installation under these conditions the equipment would be so arranged as to permit the Rome operator to call a special B operator at Florence, who would carry out the toll offering and toll breakdown. In a permanent installation, also, both way working would probably be used, so that a Florence operator could also pick up the line and dial a Rome subscriber, at the same time making the line busy to the Rome operator.

It should be mentioned that this particular application of the four frequency toll signalling system is only one of several possible and it is not necessarily suited to all conditions. The four frequency system is able to provide code impulses (using different combinations of the four frequencies for each digit) so that a Rome operator could set up a register in Florence by means of a key set instead of a dial. Such an arrangement enables the operator to carry more traffic and reduces her errors, and is therefore to be preferred to the dialling system.

Power Plant for Unattended Automatic Telephone Exchanges

By E. WOLLNER

IN view of the increase in the number of automatic exchanges, and especially of small rural exchanges, it has become necessary, for economic reasons, to adopt means for reducing the supervisory staffs. The machine switching part of the exchange is now so highly perfected that it will operate satisfactorily without constant supervision. A further step is to apply to the power plant of the exchange automatic controlling devices whereby the whole can be left without attendance during certain time intervals. As the number of available trained personnel is rather limited and as their salaries constitute an appreciable part of the maintenance charges, the advantages that accrue from avoiding the necessity for continuous supervision of the exchange are obvious.

The present account is concerned with automatic regulation of machines and automatic charging of the exchange batteries. The problem is not new; in fact, several solutions have been proposed.

The systems introduced with a view to automatic control of the power plant equipment may be divided into two classes. To the first of these classes belong systems developed for the purpose of regulating the working of the machine and of the switches from some distant point. Current impulses, sent over special wires, are used to govern the operation of power switches, circuit breakers, etc., in the distant power stations. A system of this type entails rather intricate apparatus, and initial cost is rather high compared with the cost of the telephone power plant. For this reason remote control is considered to be uneconomical for the purpose mentioned.

A solution to the problem was sought in the second class of system—the application of local control to power plants. The basic principle here is not to interfere with the working of the power plant from an outside point, but to leave the control to a few voltage and current operated instruments located in the power room itself. These instruments are so constructed and adjusted that the voltage of the battery is automatically kept to a predetermined value and the charging machine is automatically started or stopped according to the condition of the battery.

The various functions of a local control system for power plants are carried out by the following apparatus:

(a) A relay designed in the form of a voltmeter, the pointer of which stands in the rest position between two contacts, the left one of which will be touched by the pointer when the voltage drops below a certain value and the right one when the voltage rises above a certain predetermined value. As the contacts are adjustable, the control circuits, which are closed by the pointer, can be properly adjusted.

(b) An ampere hour meter, consisting of a simple form of mercury motor provided with four sets of contacts.

The first contact (No. 1) acts simply as an earth connection; the remaining three contacts designated, respectively, "No. 2 Stop charge," "No. 3 Start charge," and "No. 4 Alarm" are wiped over by a mobile arm. Contact No. 3 is fixed at a point corresponding to 10% of the total battery discharge (Figure 1-A). The fourth and last contact is intended to close an alarm circuit to the Main Exchange, at a point corresponding to 35% of the total battery discharge, when, during the travel of the arm over contact No. 3, the charging set does not start up (Figure 1-B). The alarm segment on the meter extends from the 35% discharge point to the full discharge point, and thus gives a prolonged alarm.

(c) A set of relays, the working of which is governed by the apparatus mentioned under (a) and (b), which in turn operate a motor-driven rotary switch and a level switch.

In the following, an application of the local control system will be described for the case of a power plant which consists of a storage battery having 25 cells, and of a charging set composed of a three-phase A.C. motor directly coupled to a D.C. charging generator. In order

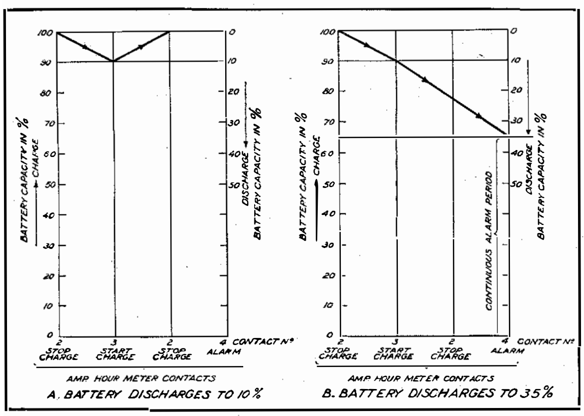

Figure 1—Battery Control Points—Power Plant for Unattended Automatic Exchanges.

to keep the voltage at the bus-bars as close to 48 volts as possible, use is made of 7 C.E.M.F. cells connected in series with the main battery. By an automatically driven switch, the individual C.E.M.F. cells are cut in or cut out according to the prevailing voltage condition. A D.C. motor provided for the drive of the rotary C.E.M.F. cell switch is constructed in such a way that it can rotate in either direction. The fundamental charging circuit is shown by heavy lines in Figure 2. The auxiliary circuits by which the automatic regulation of voltage and the starting or stopping of the charging set is effected are indicated by thin lines.

The operation of most of the relays in the auxiliary circuits is governed by the voltmeter-relay or by the ampere hour meter. The voltmeter-relay is connected across the buss-bars. The ampere hour meter is placed in the lead between the charging machine and the main battery.

The relays are grouped according to their various functions. One set is for raising or lowering the battery voltage (see relays marked "low" and "high" in Figure 2), another set for starting and stopping the machine (see sets marked "start" and "stop").

The voltmeter relay and the ampere hour meter with its associated relays provide for automatic control of the power plant, which, therefore, can be left totally unattended, though —as will be explained later—means are also provided for manual operation if that becomes necessary.

Let us now imagine a power plant of the type just described to be put into service, and let us observe how the automatic regulation is accomplished, when the battery is in use, considering each of the more important operations separately:

Voltage of Battery Drops Below 48 Volts

When the bus-bar voltage drops more than two volts below 48 volts, the contact needle of

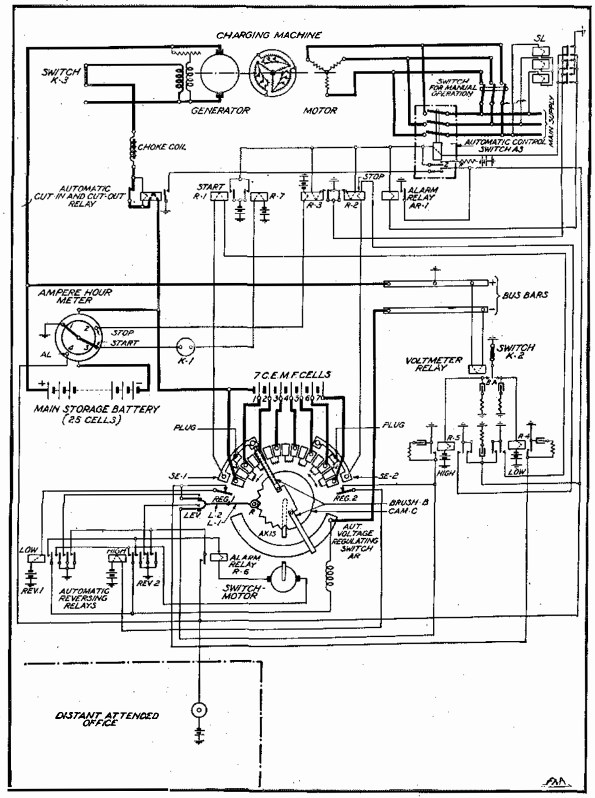

Figure 2—Circuit Schematic of Battery Charging and Local Automatic Control System. For Use with Three-phase Alternating Current Main Supply.

the voltmeter relay makes contact *A*. This closes the circuit of relay R_4 which operates and establishes another circuit over its right-hand contact. In the last mentioned circuit, the reversing relay REV_1 responds and closes by its first and second armatures the circuit of the switch motor. The automatic voltage regulating switch AR, which is of the radial pattern, therefore rotates in counter-clockwise direction, indicated in Figure 2 by a single arrow. On the axis of the motor is fixed a cam C to which are attached the brushes B of the regulating switch. During the rotation of the switch AR one of the brushes B slides over a large semi-circular contact, while the other brush B passes over a number of small metal segments. The large segment is connected to the negative bus-bar and each of the smaller ones to one of the C.E.M.F. cells. As soon as cam C commences to rotate in counter-clockwise direction, the toothed part of the cam lowers a lever arm L_1 to which a slide roller R is fastened. Correspondingly, the left-hand lever arm L_2 is raised, and the switch LEV at the end of the left lever arm becomes closed. From that time, the REV_1 relay is fed over the lever switch contact LEV and over the regulating switch contact REG_1, so that the motor continues to rotate until brush B completes the step commenced, and centres on the next segment of the voltage regulating switch, in this way cutting out one of the C.E.M.F. cells. (To simplify the circuit-drawing, individual batteries are indicated in the auxiliary circuit; it is, however, to be understood that no special batteries are required for the operation of the relays, and that the necessary current is drawn from the bus-bars.)

If the increase of 2 volts is sufficient to re-establish the voltage of 48 volts on the bus-bars, the pointer of the voltmeter relay returns to its middle position, releasing relay R_4. At the end of the step, the roller R will fall in the hollow between two teeth of cam C causing the opening of contact LEV. The circuit of REV_1 relay is now broken; this causes the opening of the circuit of the switch motor. Brush B will centre and stop on a contact corresponding to the cutting out of one C.E.M.F. cell. If the increase of voltage is insufficient, the voltmeter relay needle will remain on the contact A. The broken upper contact of switch LEV has no effect on the operation of the regulating switch, since relay R_4 is still operated, and REV_1 relay therefore continues to attract its armature, which means that the brush B will continue for another step.

Voltage of Battery Rises Above 48 Volts

When the voltage on the bus-bars is increased by 2 volts above the normal battery voltage, the needle of the voltmeter relay will close contact B, establishing the circuit of relay R_5, which operates and closes another circuit by its left-hand contact. In this last circuit, relay REV_2 operates; this, in its turn, closes the circuit of the series motor with the result that brush B will now rotate in a clockwise direction as indicated by a double arrow in Figure 2. The method of stepping of the brush B is the same as described above. Each step of the brush will introduce one C.E.M.F. cell in series with the main battery until the bus-bar voltage is automatically restored to its normal value.

Automatic Starting of the Charging Machine

There are two means provided for the automatic starting of the charging machine. In one case the starting depends on the battery voltage condition, i.e., on the voltage at the bus-bars associated with the position of the automatic voltage regulating switch AR. In the other case the switching in of the machine is a consequence of the capacity condition of the battery.

Now consider more closely the first mentioned case and, for the sake of illustration, assume that it is required that the charging of the battery should commence when the brush B is on the segment corresponding to the first C.E.M.F. cell. To insure the starting of the machine at the proper moment, a plug will have to be inserted between a sector SE_1 and a segment S_1, both of which are placed concentrically to the segments on the switch AR. It will be noted from Figure 2, that as soon as brush B arrives at the segment which is connected to the 1st C.E.M.F. cell, the extension of brush B touches the segment S_1 and that then a circuit is closed by relay R_1. This circuit can be traced from a left-hand contact of relay R_4 which has been operated via contact A of the voltmeter relay. When relay R_1 attracts its armature, another circuit is closed, which contains the operating coil of the automatic control switch *AS*. The switch *AS* connects the main supply circuit to the charging motor and causes it to start.

In the second means provided for the starting of the charging motor, the charging set can also be controlled by the operation of the ampere hour meter. If the battery is discharged to, say, 90% of its capacity (*i.e.*, 10% discharge), the ampere hour meter will close its contact No. 3. When contact No. 3 closes, a new circuit is established in which relay R_7 will be operated. The last named relay in its turn closes another circuit, which energises the operating coil of switch *AS*, and the charging motor starts in the manner previously described. The operating coil of switch *AS* is maintained active by a holding circuit which can be traced in Figure 2, from resistance *R*, to contact *Z* of *AS* and to the front contact of relay R_2.

As soon as the generator voltage is sufficiently high, the automatic cut-in and cut-out relay closes the circuit for battery charging, and if the bus-bar voltage is raised to 48 volts, contact *A* of the voltmeter relay will be opened. This, however, has no other effect, as the control switch *AS* remains operated over the holding circuit of its coil.

Automatically Disconnecting the Charging Machine

When the predetermined number of C.E.M.F. cells are introduced in series with the battery, and when the further charging of the battery is unnecessary, the machine may be stopped automatically, provided that the ampere hour meter has closed its contact No. 2, thus indicating a complete charge. When it is desired that 6 C.E.M.F. cells shall be in service to indicate the completion of the charge as regards voltage, a plug is inserted between sector SE_2 and segment S_2. When the brush arrives at the position where it touches segment S_2, a circuit will be closed by the relay R_2, which energises and locks over its front contact. Relay R_2 will remain operated until its locking circuit is opened by the subsequent operation of relay R_3 when the ampere hour meter closes its contact No. 2.

As the charging progresses, contact No. 2 will be closed when the ampere hour meter indicates the completion of the charge. At the moment that contact No. 2 is closed, relay R_3 is operated and breaks at its back contact the connection with the positive pole of the battery. This means that the locking circuit of the operating coil of switch AS is interrupted. It releases and opens the motor circuit. The charging set is thus disconnected and, in slowing down the generator current through the coil of the automatic cut-in and cut-out switch will be reduced to zero. This switch releases also, disconnecting the generator from the main battery.

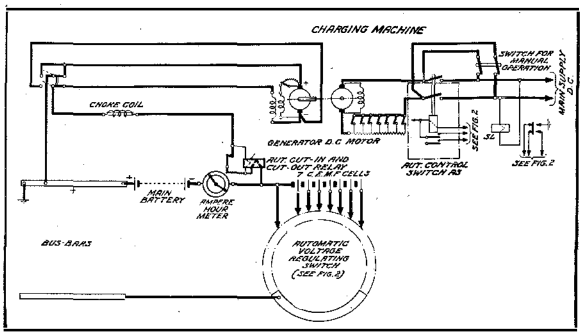

Figure 3—Circuit Schematic of Battery Charging and Local Automatic Control System. For Use with Direct Current Main Supply.

As soon as the generator has been disconnected from the battery, the voltage of the individual accumulator cells will decrease from 2.7 volts to about 2.15 volts. Thus, the voltage at the bus-bar will gradually decrease below 48 volts. When this happens, it will be necessary to cut out the 6 C.E.M.F. cells progressively, one at a time, *i.e.*, the cells placed in service during the charge, as above described. Each time the bus-bar voltage drops below 48 volts, the contact *A* of the voltmeter relay will be closed. In consequence of this, relay R_4 will be energised, causing the rotation of the automatic voltage regulating switch AR in a counter-clockwise direction, which then cuts out the C.E.M.F. cells, one at a time.

Control of Main Supply Circuit

In Figure 2 a charging circuit is indicated with a three-phase alternating current main supply circuit. The power plant control system just described can also be applied where direct current is furnished from the local power mains. In this case a few changes are necessary in the fundamental battery charging circuit, as indicated in Figure 3.

Whatever the type of supply current available, there is provision to prevent unexpected occurrences in the main supply circuit interfering with the satisfactory working of the charging machine. Special relays are provided to disconnect the operating coil of the automatic control switch *AS* every time the main supply circuit is disturbed. If alternating current is used, then for every condition a separate supervisory relay *SL* is employed (see Figure 2), whereas in the case of D.C. supply, one such relay (see Figure 3) is sufficient. When, owing to some outside trouble, one of the *SL* relays releases its armature, then the locking circuit of the *AS* coil will be opened, and the automatic control switch will disconnect the motor from the main supply circuit.

Supervisory and Alarm Circuits

To insure the satisfactory operation of the power plant, and to avoid damage to the vital part of the equipment owing to unexpected troubles, a few special circuits are provided.

To limit the movement of the rotary switch *AR* use is made of the contacts REG_1 and REG_2. If, for instance, the switch *AR* continues its counter-clockwise rotation after having cut out all the C.E.M.F. cells, the brush B will butt against and open the contact REG_1, so that any subsequent closure of the voltmeter relay contact *A* will have no effect on the switch motor. Under these conditions, the closure of contact *A* will operate relays R_4 and R_1 and will thus start the charging set, as previously described.

Similarly, the contact REG_2, at the right-hand side of the switch *AR* limits the clockwise rotation of this switch, when the maximum number of C.E.M.F. cells has been put into the circuit, thus preventing the switch from moving beyond the last position. The method of stopping the switch motor is analogous to that described in connection with the counter clockwise rotation.

Precautions are also taken to anticipate the occurrence of irregularities in the working of the power plant, in which case warning signals are sent to the distant attended Main Exchange. The corresponding alarm circuit consists of a signal wire between the exchanges, and also of a bell and a battery connected as in Figure 2. An automatic alarm signal will be sent to the attended exchange in each of the following cases:

(1) When one of the supervisory relays SL releases its armature. If *SL* fails to operate whilst switch *AS* has closed its contacts, the alarm relay AR_1 will attract its armature and an alarm will be given indicating power failure during the charging operation.

(2) When the right-hand contact of the automatic cut-in and cut-out switch closes at the same time that the remote control switch AS is operated. In this case the alarm indicates that the automatic cut-in and cut-out switch is not operating while the charging machine is running.

(3) When the reversing relays (REV_1 or REV_2) are operated, but alarm relay R_6 is at rest. This alarm indicates that the circuit for the switch motor is closed, but that its armature circuit is open, thus preventing the motor from rotating.

(4) When the voltmeter relay operates to close either its *A* or *B* contacts. Normally, these contacts should only be closed intermittently for short intervals until the conditions causing the voltmeter needle to leave its centre position are corrected. This intermittent closing happens in cases of low or high voltage as previously described. Short, intermittent alarm signals, therefore, indicate normal operation, but a continuous alarm would mean that the condition is abnormal and requires attention.

(5) When—owing to defective operation of the charging set—the alarm contact on the ampere hour meter closes, the alarm in this case is continuous.

(6) When one of the fuses (not shown in the circuit) of the charging or discharging circuit blows.

Manual Operation

It may sometimes be required to operate the power plant manually instead of automatically. This is made possible by temporarily disabling the automatic operation, and by putting into service the equipment for manual handling. When, for instance, during overcharge, manual operation is required, then switches K_1 and K_2 are opened. These switches temporarily disable the local contacts of the ampere hour meter and of the voltmeter relay, which means that automatic control is discontinued.

In addition to the above, a switch is introduced into the generator circuit (see switch K_3

in Figure 2) to change the connections from counter compound for automatic operation to a regular shunt connection for hand operation. Further, a switch is provided in the motor circuit to connect the power supply, independently of the automatic control switch *AS*. The hand operation of the complete circuit works in the well-known manner.

Conclusion

In developing an automatically controlled power plant for unattended telephone exchanges, it has been the aim to solve the problem without intricate apparatus. The practical application of the system described has proved that it covers all essential requirements without excessive first cost or maintenance charges.

Figure 4, which shows the front equipment of a power board installed in the automatic telephone exchange at Jerez (Spain), indicates the more important apparatus described in this paper.

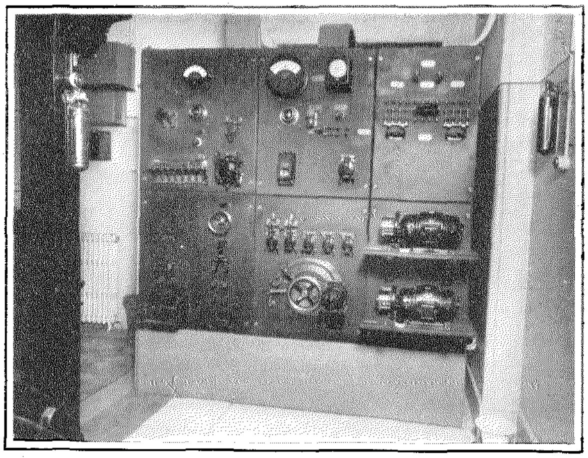

Figure 4—Front Equipment of Power Board. Automatic Telephone Exchange, Jerez, Spain.

An Electrical Frequency Analyzer*

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FOR the detailed study of sounds, of electromagnetic induction in communication lines by power circuits or composite electrical waves comprising various frequencies, etc., it is often necessary to separate and measure the constituent frequencies. For this purpose the so-called electrical frequency analyzer may be conveniently used. By the use of the electrical frequency analyzer it is possible to analyze and record not only so-called higher harmonic waves but also any waves which comprise a number of different frequencies. With a harmonic analyzer which is used to analyze wave forms from their oscillograms some inconvenience is experienced when wave forms other than harmonics are comprised in a wave form to be analyzed. The various methods which have been employed heretofore for analyzing frequencies electrically utilize the selectivity of an electrical tuning circuit[1], the longitudinal resonance of an iron bar,[2] or a low path wave filter having an extremely low cut-off frequency.[3]

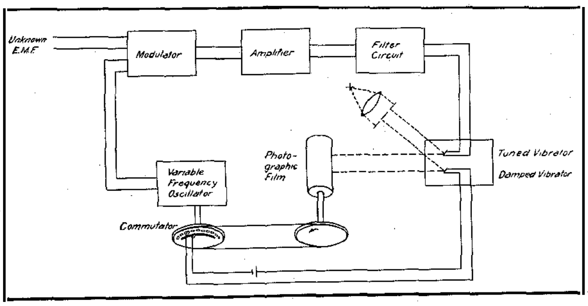

Figure 1—Schematic Drawing of the Frequency Analyzer.

The writer has recently conducted experiments with a design of electrical frequency analyzer which would appear to possess advantages not found in any other or previous types. It is the purpose of this paper to describe the theoretical considerations involved in its design, as well as the practical application of these principles, and to show some examples of the result obtained through the use of this interesting and, we believe, novel development.

1. *Outline of the Analyzer*

Figure 1 is a schematic drawing of the device. The variable frequency oscillator used with this analyzer is capable of generating currents varying in frequency from 7,530 to 14,530 cycles per second. This variation is produced by rotating the dial shown in the drawing through 180 degrees. The output from this variable frequency oscillator passes out to a modulator where it is modulated by the wave to be analyzed. If the frequency of the current to be modulated is F and that of the higher harmonic to be analyzed is f, three currents of frequencies F, F+f and F−f, respectively, are produced by modulation, as is well known. These currents, after being amplified by an amplifier and passing through a tuning circuit, flow into the vibrator shown

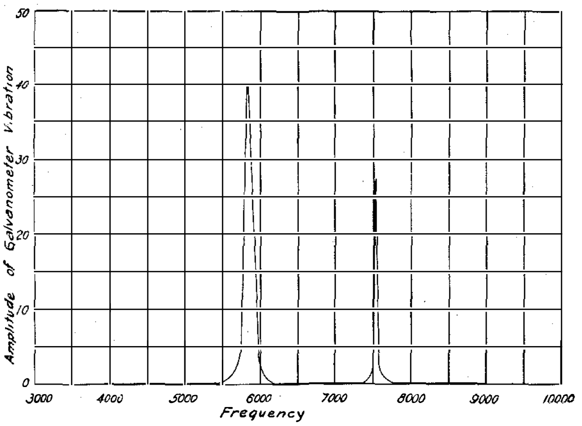

Figure 2—Relation Between the Frequency and Amplitude of Oscillation of Tuned Vibrator.

in the drawing. The vibrator consists essentially of two conductors, mounted with a small mirror and stretched across a magnetic field. Light emanating from a special lamp is reflected from this mirror and projected upon a photographic film mounted upon a rotatable drum.

[1]R. L. Wegel and C. R. Moore, *Bell System Technical Journal*, April, 1924, pp. 299-323.

[2]C. R. Moore and A. S. Curtis, *Bell System Technical Journal*, April, 1927, pp. 217-229.

[3]M. Grützmacher, Zs f. *Techn. Phys.*, Aug., 1927, pp. 506-509.

*Presented before World Engineering Congress, Tokyo, Section 6, October 31, 1929.

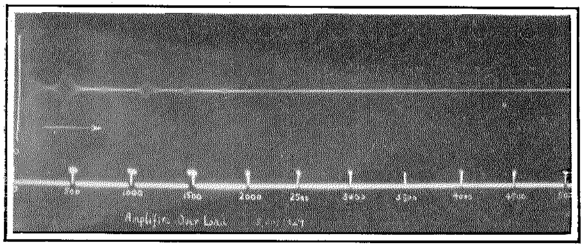

Figure 3—Harmonic Production of Overloaded Amplifier.

The vibrator has, usually, two tuning frequencies, as shown in Figure 2. Hence, if the resonance frequency of the tuning circuit is tuned to one of the tuning frequencies, say 7,530 cycles per second, the oscillation of the vibrator becomes marked only for this frequency. Now, if the frequency F is so varied that one of the frequencies $F \pm f$, say $F-f$, becomes 7,530 cycles per second, the vibrator starts its oscillation. Since the oscillation of the vibrator is proportional to the magnitude of the modulating current, it is proportional to the magnitude of the higher harmonic of frequency f. Therefore, if F is given a value ranging from 7,530 to 14,530 cycles, a current having a frequency ranging from 0 to 7,000 cycles per second may be analyzed. As the tuning characteristic of the vibrator is sharp, as shown in Figure 2, fairly accurate measurement can be made.

Now, the light oscillating in accordance with the oscillation of the mirror is projected upon a drum, as shown in Figure 1. Since the drum is wrapped with a light sensitive film, the latter is affected in a degree corresponding to the amplitude of the oscillation. If, as shown in the drawing, the drum and the dial of the variable frequency oscillator are so coupled that the drum makes one complete revolution when the dial is turned 180 degrees, the former makes one complete turn when the frequency of the current from the variable frequency oscillator is changed over the range of 7,530 to 14,530 cycles per second, corresponding to the 180 degrees turn of the dial. Since large oscillations are produced in the vibrator only when $F-f$ equals its resonance frequency, a series of oscillations as photographed in Figure 3 is produced as the drum is turned. In this figure it is seen that harmonics or component frequencies are arranged in the order of their frequencies and corresponding to their magnitudes.

The angular displacement of the drum desig-

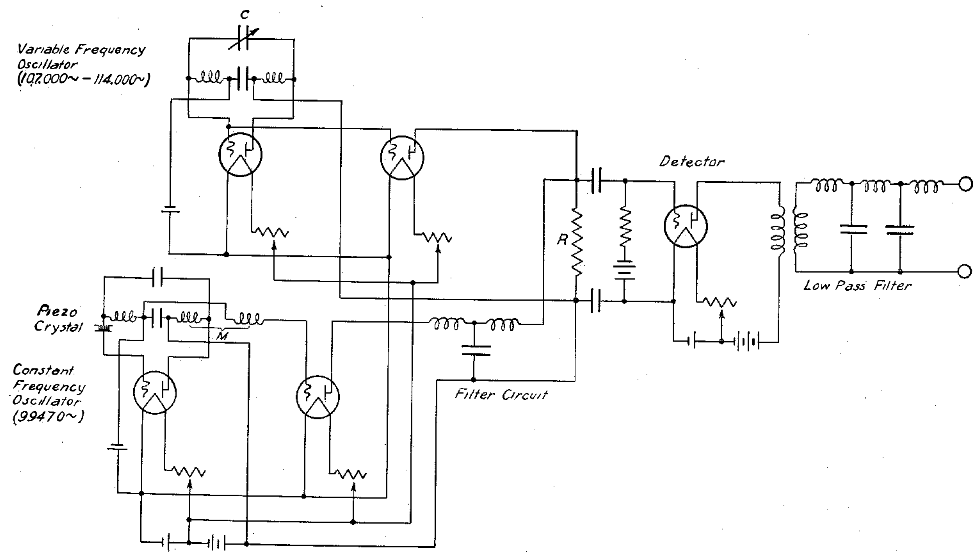

Figure 4—Beat Frequency Oscillator. (Frequency Range from 7530 Cycle to 14530 Cycle.)

nates a change in the frequency of the current output from the oscillator as was mentioned above. Hence, if contacts are provided for the dial, as shown in Figure 1, to indicate frequencies corresponding to dial positions, one of such

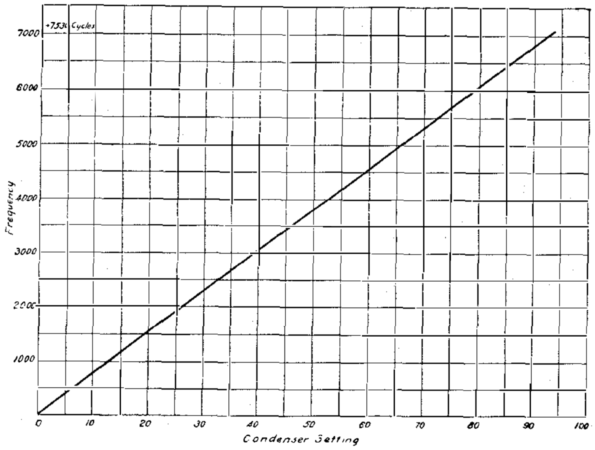

Figure 5—Frequency Characteristic of Beat Oscillator Corresponding to the Dial Setting of the Condenser.

contacts being provided at, say, every 1,000 cycles per second, so that the brush attached to the dial sweeps over these contacts, a scale graduated in frequencies, as shown in Figure 3, to correspond to the displacement of the drum, may be obtained. Arrangement may be made as shown in the figure to supply current to other vibrators through these contacts.

2. *Double Frequency Oscillator*

It is necessary to keep the output of the oscillator constant throughout the frequency 7,530 to 14,530 cycles per second, produced by turning the dial through its complete range. This is accomplished by utilizing the beat of two currents as shown in Figure 4. For this purpose two oscillators may be employed, one of constant frequency and the other of variable frequency. Since stability is required of the constant frequency oscillator, a piezo oscillator capable of producing oscillations of 99,470 cycles per second is used. For the variable oscillator an ordinary valve oscillator, as shown in the figure, is used. If the condenser C is turned 180 degrees, it generates oscillations over the range of 107,000 to 114,000 cycles per second.

After the oscillatory currents from the constant frequency oscillator and the variable frequency oscillator are amplified respectively, and higher harmonics are eliminated from them by filters, these oscillatory currents are superposed through a resistance R to produce a beat. The terminal voltage of this resistance R is impressed on the grid of the next valve and is detected. Hence, if a transformer is connected to the output side and if the voltage is impressed on a low path filter, a beat frequency may be produced. For this purpose a filter having 50,000 cycles for the cut-off frequency may be used. Figure 5 shows the variation in frequency with changes in condenser degrees. It is seen that the rise in frequency is approximately proportional to the increase in the condenser setting, and the output current is almost constant over the frequency range required.

3. *Analyzing Circuit*

Figure 6 is the analyzing circuit employing grid modulation. If the waves to be analyzed are applied to circuit I and those to be superposed to circuit II, and if the secondaries of I and II are connected in series with the grid of the modulating valve, the latter waves are modulated by the former waves. The waves thus modulated are then amplified, and applied through a tuning circuit to the vibrator. Since in this analyzer a vibrator having very low

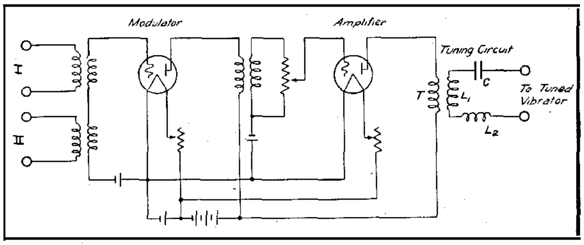

Figure 6—Analyzing Circuit Using Grid Modulation.

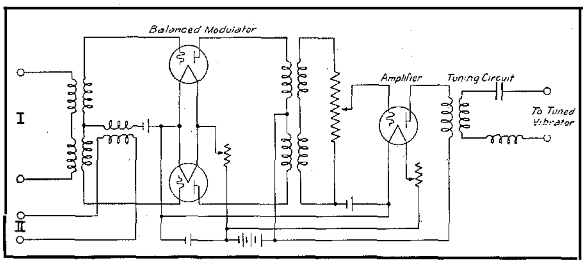

Figure 7—Analyzing Circuit Using Balanced Modulator.

resistance is used as described later under "Tuned Vibrator," a high step-down ratio of transformation is selected for the transformer T. If a tuning circuit is established with L_1, L_2, and C, the current which flows in this circuit is mainly of frequency $f_o = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$, currents of other frequencies being largely suppressed. If f_o is tuned to one of the resonance frequencies of the tuner, the tuner vibrates only

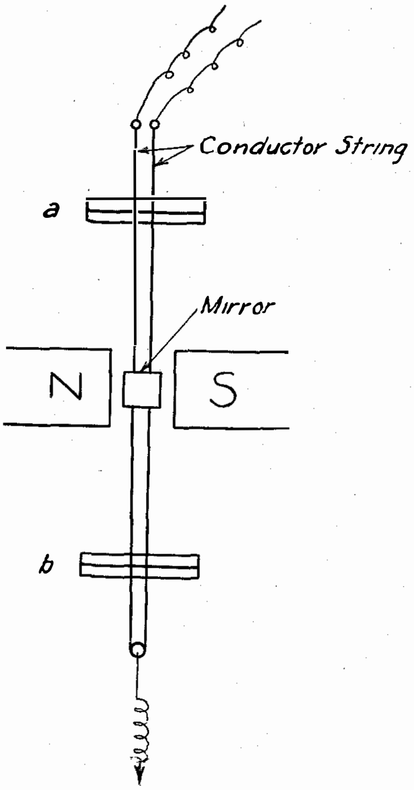

Figure 8—Schematic Drawing of Tuned Vibrator.

for f_o, and consequently analysis can be made with this circuit.

According to this method, which depends on grid modulation, frequencies F and $F \pm f$ are produced and the vibrator oscillates, even when $f = O$, as shown in Figure 3. Though some inconvenience is introduced in this method for the analysis in the neighborhood of zero cycles, this inconvenience is avoided, if a balanced modulator shown in Figure 7 is used and the carrier is suppressed.

4. *Tuned Vibrator*

The tuned vibrator consists of two conductors stretched across a magnetic field as indicated in Figure 8, the conductors being subjected to considerable tension between blocks a and b. At the mid-point between a and b is mounted a small mirror. The tuned vibrator is, therefore, of the same construction as the vibrator element of the Duddel oscillograph.

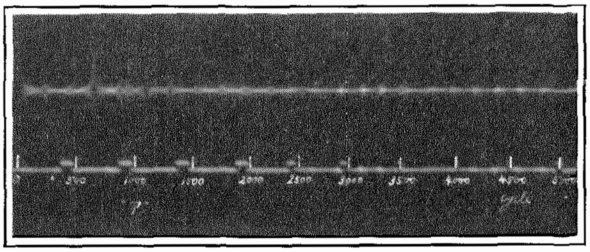

Figure 9—Vowel "a" short as in ah.

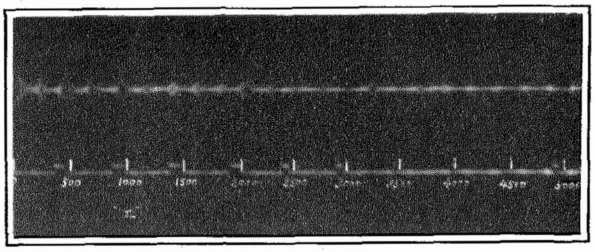

Figure 10—Vowel "a" long.

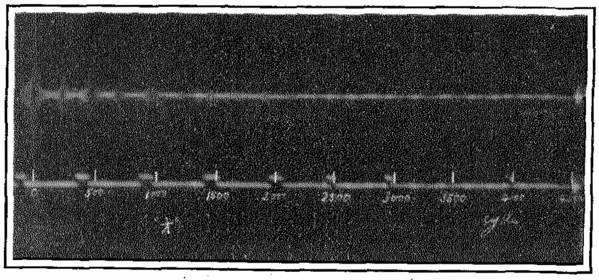

Figure 11—Vowel "o" long.

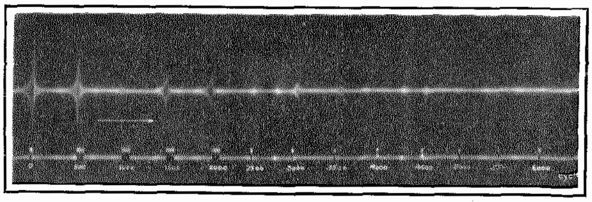

Figure 12—Harmonic Production When Alternating Current of 500 Cycle is Rectified by Two Electrode Vacuum Tubes

As is well known, the natural frequency of a stretched string is expressed by

$$f = \frac{1}{2}\sqrt{\frac{T}{lm}}$$

where T is the tension, l the length, and m the mass of the string. Now, if two conductors are connected in series as shown in the figure and a current is passed through these conductors, a certain angular displacement about the central axis is produced for the mirror. If the current passed is an alternating current the mirror vibrates about its central axis.

Since the stretched conductors have their natural frequency as mentioned above, if the frequency of the alternating current flowing through them coincides with this natural frequency, obviously the amplitude of the vibration becomes very large.

Figure 2 shows the variation in the amplitude of oscillation for varying frequencies when the current or the torsional force for the conductors is kept constant. From this it is seen that there are two resonance frequencies. This phenomenon has already been described* and is attributed to the difference in the natural frequencies of the two conductors. Since the existence of these two resonance frequencies introduces some inconvenience for the purpose of analysis, it is advisable to eliminate one of them. This is easily accomplished by the use of an electrical filtering device which is incorporated in the tuning circuit shown in Figure 6.

Since the sharpness in sensitivity depends on the friction of the moving part of the vibrator, it is not advisable to immerse the whole moving part in oil as in an ordinary oscillograph. It is thought that if the moving part is kept in a vacuum and the friction due to air is reduced, better results will be obtained.

5. *Examples of Application*

Using the frequency analyzer just described, the author has studied some electric and acoustic phenomena with rather interesting results. Since, however, the object of this paper is chiefly to describe the principle upon which the new analyzer is based, and a detailed description of all the various experiments and applications would be too long and beyond the scope of this paper, only a few examples of its practical application are shown herein.

Figure 3 is an example of harmonic production when too much voltage is impressed on the grid circuit of an amplifier. Figure 9 is "a" short as in ah. Figure 10 is "a" long and Figure 11 is "o" long. Figure 12 is an example of harmonic production when alternating current of 500 cycles is rectified by a two electrode vacuum tube.

In these examples, the carrier current is seen at the position of zero cycles, as grid modulation is used.

*Aoki, Tada and Tomoda, *Journal of Japanese Inst. E. E.*, Oct., 1928, pp. 1065-1114.

The Determination of the Desirable Attenuation-Frequency Characteristic of a Long Toll Circuit

By A. R. A. RENDALL

International Standard Electric Corporation

SUMMARY. This article discusses the relative effects of phase and attenuation distortion on long toll cable circuits. It describes a series of tests made to show that the "tweet" noise introduced by phase distortion can be diminished by increasing the attenuation of the higher frequencies, without reducing the intelligibility of speech received over the circuit. The paper concludes by outlining certain cable plant studies which should be made before changes in loading systems are contemplated.

THE ideal overall attenuation-frequency characteristic of a long distance circuit has been a much discussed question in recent years. For some time it has been almost universal practice to equalise, to some extent, 4-wire circuits, especially medium heavy loaded circuits. The extent and method of equalising attenuation has varied from case to case, but it may be generally stated that the majority of Administrations have assumed that complete equalisation provides the ideal overall circuit characteristic.

In 1926 the C.C.I.[1] considered the question of the overall loss frequency characteristics of 4-wire and 2-wire circuits, and recommended that the circuits should be equalised within certain limits. According to the rule laid down, the overall circuits could be over equalised or under equalised.

In the application of the system designated 1A by the C.C.I. (*i.e.*, that adopted by the International Standard Electric Corporation), the practice has been always to under-equalise.

On 4-wire circuits, the one-way paths were fully equalised, and then 4-wire terminating sets were added, the transmission loss of which increased slightly with frequency. In the case of 2-wire circuits, the practice has been to employ 2-wire repeaters with flat or slightly rising gain characteristics, so that the overall loss of the circuit increased considerably towards the higher frequencies.

The recent tendency has been to narrow these limits within a defined frequency range, so that the overall characteristic more nearly approaches complete equalisation. At first sight this policy may appear to lead in the right direction, but it cannot be maintained that it is based on experimental evidence. The practice is therefore still open to challenge in the light of more definite knowledge.

The problem will first be examined theoretically and then the results of field trials will be recorded.

Consider, first, a one-way coil-loaded circuit, equipped with amplifiers whose pass range can be varied at will, and suppose that the repeater cut-off is progressively increased from a low value of frequency to one approaching the natural frequency of the circuit. If no other form of distortion were present, as each additional frequency band was added, the circuit intelligibility would increase. This intelligibility could be measured in terms of syllable or word articulation, or idea intelligibility. All these quantities are related as shown by John Collard (see C.C.I. Green Book—1928, Appendix 7, or *Electrical Communication*, January, 1929)[2], but great care must be taken in the use of these terms, when the quality of a circuit is expressed.

The telephone subscriber is really interested in idea intelligibility or "Time Efficiency" (as defined by Collard in the above references), and syllable articulation is a necessary step in the determination of the quality of a circuit. For example, a statement that the syllable articulation of a circuit is 70% may convey the wrong impression of the value of a circuit, but the equivalent "Idea Intelligibility" of 93% shows that the circuit is a good commercial circuit.

The effect of the frequency-band passed on the

[1] Comité Consultatif International.

[2] A Theoretical Study of the Articulation and Intelligibility of a Telephone Circuit, *Electrical Communication,* January, 1929.

circuit articulation or intelligibility has been studied by several investigators, and the published results are supported by a large amount of experimental evidence. Figure 1 reproduces the syllable articulation cut-off frequency curve shown in Figure 136 of "Speech and Hearing" (Fletcher), and includes an idea intelligibility

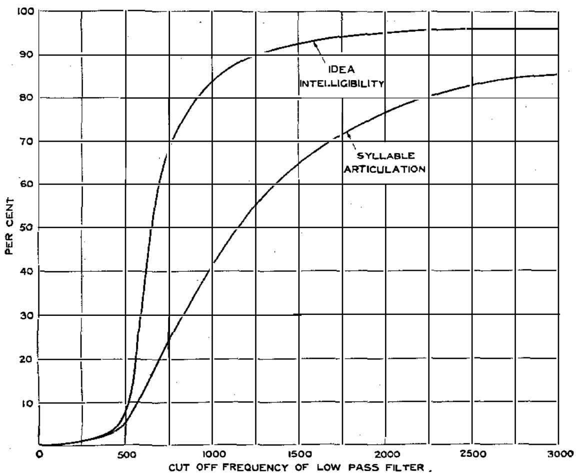

Figure 1—Idea Intelligibility and Syllable Articulation—Cut-off Frequency Curves.

(Reproduced by the kind permission of the publishers, D. Van Nostrand Company, Inc., New York, from Dr. Harvey Fletcher's book "Speech and Hearing.")

cut-off frequency curve for a high quality circuit. The latter curve was calculated from the former by the methods described by Collard in the article already mentioned. From these curves it will be observed that an increase in the circuit cut-off from 2,000 p.p.s. to 2,400 p.p.s. adds about 6% to the syllable articulation, and only 1% to the idea intelligibility.

It may be objected that these curves, derived by the use of high quality apparatus, do not fairly represent the normal commercial case. The tests described later, show that similar conclusions apply for circuits using commercial subscribers' sets.

Returning to the consideration of the one-way circuit, as the circuit cut-off frequency is raised, and approaches the natural frequency of the loaded cable, another effect is introduced, that of transient distortion. It is well known that the higher frequency components of speech are propagated along a loaded cable at a much smaller velocity than the lower frequency components. The quantity which expresses the magnitude of transient distortion is $\frac{d\alpha}{d\omega}$, where the cable propagation constant is $P = \beta + j\alpha$, and $\omega = 2\pi x$ frequency. Figure 2 is a plot of this quantity, which may be regarded as time delay for a loading section of cable. It will be noted that the delay at 0.87 of the cable natural frequency is twice that at 0.2 of that frequency.

The high frequency components of speech will therefore arrive in incorrect time order, and this will affect the quality of received speech. On the shorter circuits the effects will not be noticeable; but as the circuit length is increased, a noise is introduced which can best be described as "tweet." This "tweet" is most noticeable after the more prominent consonants have been pronounced, and is due to the delayed high energy peaks arriving at a time when the speech energy is low. This noise interferes with speech, by distracting the listener's attention. When the circuit length is increased still further, blurring will result, and the syllables will become indistinct. This effect is similar to that produced by frequency distortion. In view of the disturbing effects of the higher frequencies due to transient distortion and to their small contribution to articulation, a

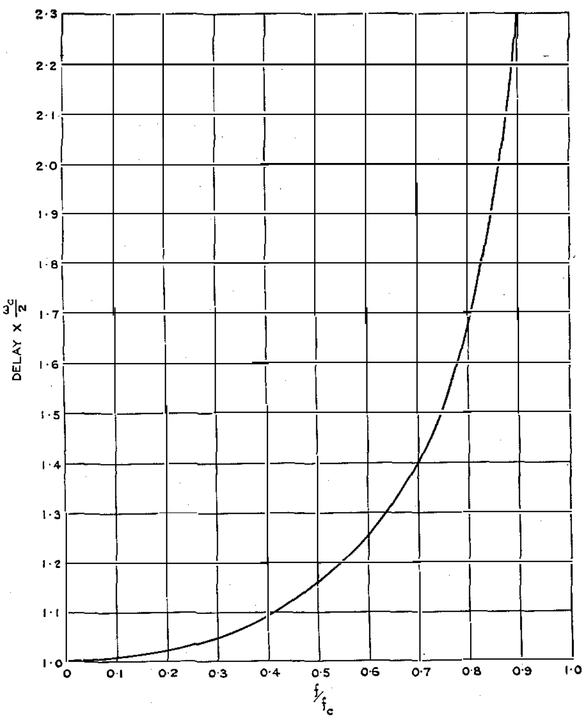

Figure 2—Delay Characteristic of Loaded Cable Circuit.

doubt can be reasonably expressed whether the presence of these frequencies at full volume is desirable.

It may be urged that the transient distortion should be limited, by raising the cut-off of the cable or introducing phase compensation. Either of these expedients would increase the circuit cost, and before such a course is taken it must be established that definite improvement is obtained, under working conditions, by transmitting these higher frequency components at full strength.

It therefore seemed necessary that field tests should be made to determine the desirable frequency range and attenuation characteristic of long circuits. Tests with this end in view were carried out by the International Standard Electric Corporation in France, Belgium, and Holland, by the kind permission of the Administrations concerned.

In 1927 preliminary tests were carried out on the Paris-Strasbourg cable, by the courtesy of the French Administration. A long medium heavy 4-wire circuit was set up and equipped with filters, so that a series of articulation tests could be made with different circuit cut-off frequencies. It was then observed that the detrimental effect of transient phenomena upon the utility of a telephone circuit could be divided into two distinct classes, as already noted. The total amount of syllable blurring caused by the limitation of the transmission band on one hand, and the transient phenomena on the other, when the circuit cut-off was varied from 1,800 to 2,400 p.p.s., did not vary appreciably. This was demonstrated in the articulation tests by the fact that a nearly constant percentage of syllables was correctly received for the various cut-off frequencies. The noise effect of the transients, however, increased most noticeably as the circuit cut-off was raised; but while its presence introduced a mental strain in listening to the syllables, it did not appreciably reduce the percentage of syllables correctly heard. From this it may be deduced that while the transient noise effect does not impair the reception of a syllable or word deliberately pronounced, it may distract the listener's attention so that he cannot group words into ideas so readily. It is quite clear that if two circuits exist, which give equal syllable articulation, the better circuit is the one with the smaller noise interference. At the tests made in Paris, numerous persons were asked to talk on the circuit, under different conditions of cut-off frequency, and all agreed that the circuit was better when the higher frequencies were attenuated.

The results of these tests indicated that a more complete field trial was desirable.

The opportunity arose in September, 1929, when the Belgian Administration kindly agreed to loan the circuits necessary for these trials.

The circuits actually set up are shown in Figures 3 and 4, and were in accordance with the C.C.I. system 1A. The cable constants were as follows:

Loading Coils................0.177 Henry
Loading Spacing..............1,830 metres
Loading Section Capacity.....0.070 mfd.
Cable Natural Frequency.....2,850 p.p.s.
Conductor diameter...........1.3 mm.

Figure 3 shows, diagramatically, the 2-wire side circuit, having a total length of 545.6 kms., and

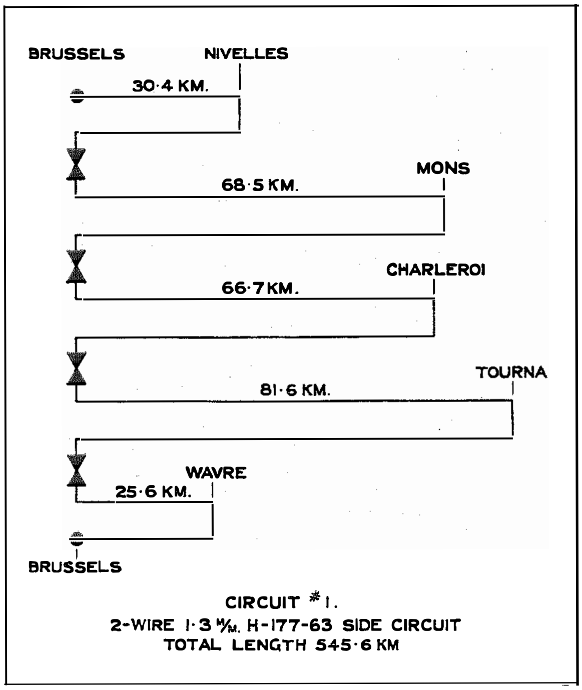

Figure 3—Experimental 2-Wire Circuit.

arranged with four 2-wire repeaters in tandem. A duplicate circuit of the same layout was set up for the purposes of direct comparison. Figure 4 shows the 4-wire side circuit, 864 kms. in length. Several weeks were spent in making articulation

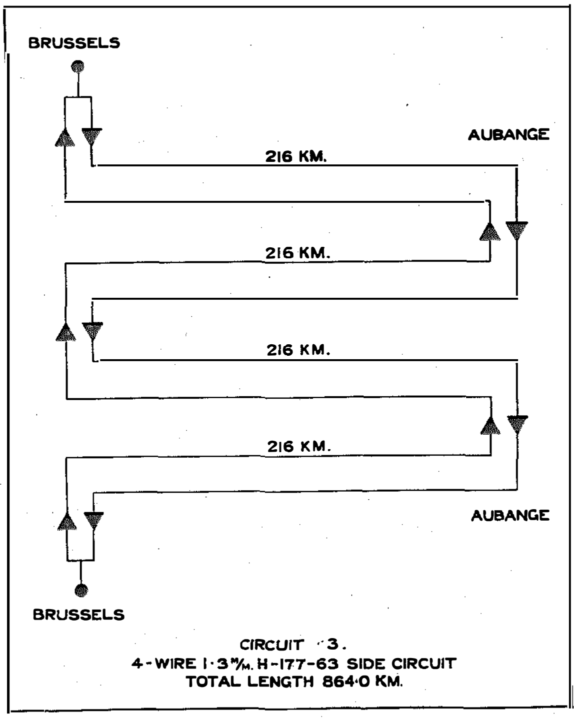

Figure 4—Experimental 4-Wire Circuit.

tests on these circuits, with various types of attenuation characteristics.

Before these tests are described in detail, it is necessary to explain the methods of making articulation tests which were adopted. Lists of specially selected words had been prepared, as the result of a careful examination of the English language. The frequency of occurrence of the sounds comprising spoken English had been determined, and these were incorporated into words of two or three sounds, so that a complete list of 80 words contained the sounds in proportion to their frequency of occurrence in the language. The words selected were ordinary English words, and therefore the results of the tests are in terms of "Word articulation." This method had been tried in the laboratory and had given excellent results. The expected accuracy of observation of word articulation, with the number of observations taken under each condition, was within ± 2%, although it is interesting to note that it was possible to repeat results with greater accuracy.

Three English observers made the articulation tests. Each man in turn pronounced a list of 80 words, and the other two men listened in parallel at the far end of the circuit, in two separate silence cabinets. In this way one complete set of tests produced six observations. In order that the circuit conditions should approach as nearly as possible to a normal subscriber-to-subscriber connection, commercial sub-sets were employed and connected to the line, through a network designed to simulate a 300 ohm subscriber's loop and standard cord circuit arrangements.

The first tests were made on the 2-wire circuit, Figure 3. The four intermediate 2-wire repeaters were located at Brussels, so that they were under the control of the observers. By changing the tuning circuit of these repeaters, different types of gain-frequency characteristics could be assigned to them. In this manner different overall attenuation-frequency characteristics could be obtained on the circuit. The three-circuit characteristics tested are shown in Figure 5. Curve A results from a rising repeater gain characteristic adjusted to equalise for the cable distortion. Up to 2,200 p.p.s., the equalisation is close, and the condition may be described as "fully equalised." At the two ends of the frequency scale, the repeaters "cut off." Curve B is the case where the intermediate repeaters had substantially flat gain-frequency characteristics over the frequency range 300–2,200 p.p.s.,

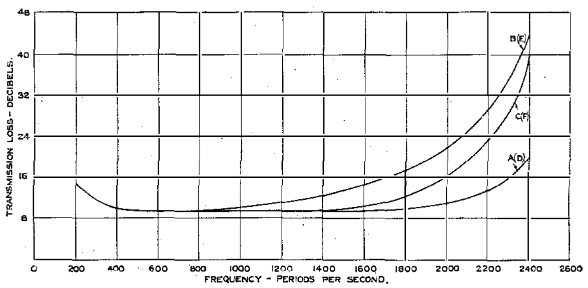

Figure 5—Loss Characteristics of Experimental 2-Wire Circuit.

and consequently the rise in the cable attenuation, with frequency, was not compensated. Curve C corresponds to an intermediate case. For the three conditions, the net transmission equivalent at 1,000 p.p.s. was as near as possible 10 decibels. It should be realised that for circuit B the difference in attenuation between 1,000 and 2,200 p.p.s. is over 18 decibels.

Tests were first made with the circuit cut one-way, so that the effects of echo were eliminated, and then a second series of tests were made with the circuit cut two-way. The corresponding circuit conditions for the two-way case are described as D, E, and F.

A total of 12 sets of tests, or 72 observations (each observation means the pronunciation and writing down of 80 words), were made on condition A, and 66 observations on each of conditions B and C. The average results in word articulation were as follows:

Condition A—fully equalised........86.2%
Condition B—non-equalised.........86.2%
Condition C—partially equalised....88.4%

The tests were repeated for the circuit cut two-way. 36 observations were made on each condition, and the resulting word articulation was:

Condition D—fully equalised..........86%
Condition E—non-equalised...........86%
Condition F—partially equalised......88%

Although articulation testing methods are not sufficiently precise to enable much importance to be attached to the slight increase in articulation observed on conditions C and F, compared with A and D, yet in view of the corroboration evidence of tests described below, it can be stated that the word articulation for the non-equalised circuits is not less than that for the equalised circuits. This confirms the facts observed during the Paris tests, that the total syllable blurring, due to the effects of frequency and transient distortion, remains constant when the attenuation of the high frequency components is varied within the limits of the tests described.

The noise due to the transient distortion, however, was annoying for conditions A and D, and was absent for conditions B and E. On the partially equalised circuits, it was just noticeable. In order to establish this fact, a second 2-wire circuit was arranged, with length and layout the same as the first. This enabled a rapid change to be made from one condition to the other during a conversation. A number of persons were asked to converse over the circuit and to express their opinions. They were informed of the circuit condition by the naming of letter designations allocated to each circuit. Those who talked included three members of the Belgian Administration, five French-speaking, and three English-speaking members of the company.

It was unanimously agreed that a fully equalised circuit was the worst circuit to talk over because of the "tweet" due to transients. Little difference was observed between the partially and non-equalised conditions, but a slight lack of brilliance was noticed in the non-equalised case, although the voice was reproduced quite clearly.

Whether the circuit was cut one-way or both ways had no effect on the results. In the two-way condition an echo was observed by the talker, but its magnitude and time lag were not sufficient to cause any annoyance.

Similar tests were carried out on the medium heavy 4-wire side circuit, Figure 4. This circuit was 864 kms. in length, and as already stated, its constants were in accordance with C.C.I. system 1A, and therefore it was slightly in excess of the limiting length specified for this type of circuit.

The gain characteristics were adjusted to give different degrees of equalisation; and, when required, low pass filters were added to give the desired characteristic. Figure 6 shows the various overall attenuation-frequency characteristics which were tested for articulation.

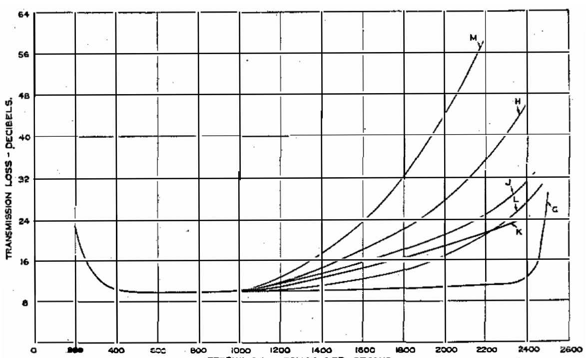

Figure 6—Loss Characteristics of Experimental 4-Wire Circuit.

The 1,000 cycle net equivalent in all cases was about 10 db. Curve G represents close equalisation up to 2,400 p.p.s., and the other curves give different degrees of distortion. Curve M represents an extreme case, which was taken to illustrate the great degree of distortion that can be tolerated, at the higher frequencies, before the "word articulation" is seriously affected. It should be realised in this particular case that the net loss at 2,200 p.p.s. is nearly 50 db. greater than the net loss at 1,000 p.p.s., and yet, from the figures below, it will be noticed that the articulation is only a few per cent lower than for the other cases.

The average percentage word articulation was as follows:

Condition	% Word Articulation
G (fully equalised)	85
H (non-equalised)	83.5
J (partially equalised)	84.5
K (partially equalised)	87.0
L (partially equalised)	86.5
M (extreme case of under-equalisation)	82.3

These results confirm the previous conclusion, which may be restated generally as follows: If on a loaded cable circuit, the attenuation frequency curve is so varied that the higher frequencies are more efficiently transmitted, a point is reached where the increase in articulation obtained by an increment of high frequency energy is neutralised by the transient distortion caused by the increased frequency range passed.

The "tweet" heard on this circuit was more marked (in view of the greater length) than on the 2-wire circuit, and the quality of the speech was much improved by the attenuation of the higher frequencies. In order that the effects of transient distortion could be observed on a very long circuit, a one-way circuit of double the length (making a total length of 1,728 kms.) was set up, and this long circuit was equalised approximately. The articulation on the equalised circuit was 81%, and when attenuation was introduced at the higher frequencies, it was 85%. Here, definite improvement was obtained by under equalisation, and the "tweet" on the equalised circuit was so troublesome that continuous speech was nearly impossible. Conversation was quite reasonable on the circuit when the high frequencies were attenuated. These opinions were confirmed by numerous people who were asked to carry on a conversation over the circuits.

Further confirmation of these results was obtained by an abridged series of tests carried out at Eindhoven repeater station in Holland.

Reviewing the results of all tests the conclusion is arrived at that, unless phase compensation is employed, there is no advantage—in fact, a positive disadvantage—in fully equalising the attenuation to a high percentage of the cable natural frequency. The higher frequency components must be attenuated to an extent sufficient to reduce the "tweet" to a value where it is not objectionable. The tests indicate that if the loss at 2,200 p.p.s. is about 12 to 15 db. greater than at 1,000 p.p.s., this condition is satisfied. The question immediately arises whether this compromise has reduced the "word articulation" appreciably from the value which would have been obtained if the band of frequencies up to 2,200 p.p.s. had been passed with complete attenuation and phase equalisation. An answer to this question can be obtained by comparing, as given below, the best compromise articulation values of short and long circuits. On the shorter circuits the transient distortion is smaller, therefore it would be expected that the best compromise value would be higher.

Length	Best articulation value obtained
545.6 kms. (2-wire one way)	88.4%
864 kms.	87%
1,728 kms.	85%

A further measure of the loss in articulation was obtained by a special test, in which the cable circuit was replaced by a distortionless artificial line of 10 db., the subscriber's loops being kept the same. The articulation value so obtained was 91%, therefore the loss from the absolute ideal, for commercial subscriber's apparatus, is as follows:

Circuit Length	Loss from ideal in	
	"Word Articulation"	Idea Intelligibility
545.6 kms.	2.6%	0.5%
864.0	4.0%	1.0%
1,728.0	6.0%	1.5%

The gain in articulation which would be obtained with an actual circuit, in which the transient distortion was reduced by phase compensation or by an increase in the cable natural frequency, must therefore be very small for lengths of 864 kms., and still smaller for lengths of 545 kms. Before such expensive expedients are adopted, it would be well for all Administrations to answer the following questions:

What number of circuit kilometres fall into different categories of length—up to 100 kms., 100–200 kms., 200–300 kms. and so on?

How much would be gained in articulation, in each class of circuits, over the best "compromise" value, if transient distortion were reduced by raising the cable natural frequency or by using phase compensation?

How much would it cost in each class of circuits to reduce transient distortion in the manner described?

The determination of these factors, so that the systems finally recommended for the European toll cable network shall represent a true balance between quality and cost, constitutes a long and complicated problem, which needs the intensive coöperation of all concerned.

Whatever the outcome of such an investigation, experience already gained indicates that an economical grade of loading, such as the medium-heavy loading of systems Ia and Ib, without phase compensation, must inevitably play an important part in national and international circuits.

The author urges that consideration should be given to the conclusions reached in this article when deciding the practices governing the over-all attenuation-frequency characteristics of toll circuits.

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