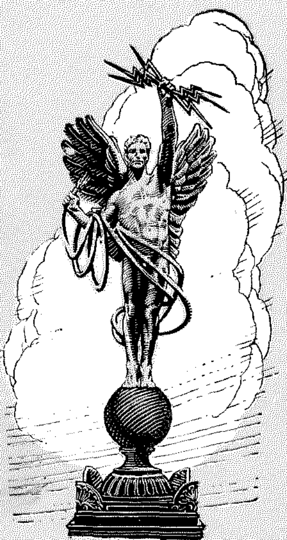
L C Pocock

ELECTRICAL COMMUNICATION



JULY
1927

No. 1
VOL. 6

ELECTRICAL COMMUNICATION

A Journal of Progress in the Telephone, Telegraph and Radio Art

Published Quarterly by the

International Standard Electric Corporation

Head Offices
41 BROAD STREET, NEW YORK, N. Y., U. S. A.

European General Offices
CONNAUGHT HOUSE, ALDWYCH, LONDON, W. C. 2, ENGLAND
75, AVENUE DES CHAMPS-ELYSEES, PARIS (8e), FRANCE

G. E. Pingree, President L. N. Rock, Secretary H. B. Orde, Treasurer

Subscription $1.50 per year; single copies 50 cents

Volume VI JULY, 1927 Number 1

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Sir Charles Wheatstone, F.R.S.

Pioneers of Electrical Communication

CHARLES WHEATSTONE—IV

By ROLLO APPLEYARD

European Engineering Department, International Standard Electric Corporation

IF from a list of names of famous men associated with the early development of electrical communication we exclude those immortalised in the designations of the electrical and magnetic units, the best known among the remainder is probably that of Charles Wheatstone; and if the telegraph and telephone engineers of the present generation were asked the reason for that electrician's undiminished popularity, a considerable proportion of them would attribute it, correctly enough, to "Wheatstone's Bridge." Nevertheless, he did not invent that device—on the contrary, he scrupulously assigned it to its true discoverer. Wheatstone's fame rests upon surer foundations; he was a pioneer in practical electrical communication, and a leader in the realms of qualitative and quantitative physical research. The memory of him lives—"not only for his discoveries and for the methods of investigation with which he had endowed science, but also by the recollection of his rare qualities of heart, the uprightness of his character, and the agreeable charm of his personal demeanor."

This last noble tribute from Jean-Baptiste Dumas, then Secretary of the French Academy of Science, uttered on the occasion of Wheatstone's death in Paris, scarcely more than half a century ago, has proved to be true beyond all that could have been imagined by his contemporaries. There are good reasons, therefore, for availing ourselves of any special opportunities that arise to renew or to extend acquaintance with the achievements and career of Charles Wheatstone. By the courtesy of the authorities at King's College, London, it has been possible recently to examine and to photograph some of the relics of his apparatus, and it is proposed here briefly to recall the part such apparatus played in the establishment of the principles of observation and measurement upon which modern electrical research is founded. The "King George III Museum" at King's College contains a collection that consists primarily of apparatus presented to the College in 1841 by Queen Victoria. It was originally brought together by George III at the Royal Observatory, Kew. To it has been added the "Wheatstone Collection" and the "General Collection." A catalogue of the whole exists, dated 1900, but there is no detailed account available of the various pieces of apparatus in the Museum.

Reference to researches to which the relics here illustrated relate, are to be found in innumerable volumes. If with these are included pamphlets of a controversial character, and articles in scientific and biographical works, the publications relating to Wheatstone become somewhat overwhelming. By judicious selection, however, the essential literature can be reduced to a few classic books and papers. So far as the scientific aspects of his achievements are concerned, the commemoration volume published in 1879 by the Physical Society of London, entitled "The Scientific Papers of Sir Charles Wheatstone" supplies all that is required for general knowledge of his discoveries and of his teaching. For an account of his work, and the work of his contemporaries, relating to telegraphy, attention must be directed to two papers read before The Institution of Civil Engineers on March 2, 1852—the first by Mr. Charles Coles Adley, and the second by Mr. Frederick Richard Window. These luminous contributions to the subject are both printed in Volume XI of the Proceedings of that Institution. To them must be added the obituary notice, written by one of his friends, which was printed in the Proceedings of the Royal Society, Volume XXIV, in 1876. In language that is at once appreciative and critical, it conveys a conception of the human side of Wheatstone, and leaves with us the impression of a man of high principle, of fine intelligence, and of invincible determination in research and its applications. What was the secret of his success? His modest early circumstances, and his immersion as a young man in commerce, could easily have made him a thriving

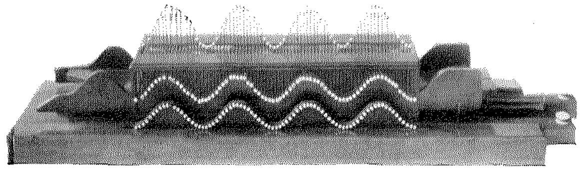


Figure 1—Wheatstone's Sine-wave Model

tradesman. But by what influences was he led along the path of research to the pinnacle cf discovery?

Charles Wheatstone was born in February, 1802, in Gloucestershire. His father, a music-seller in the county-town, removed with his family in 1806 to 128 Pall Mall, London, where he taught the flute, and made and sold musical instruments. Charles, who had received a private-school education, showed early promise of mechanical ingenuity, and as he had clear notions of dynamical principles, he was not long in giving evidence of his capabilities. In 1821 he attracted attention by exhibiting an instrument the name and construction of which prove him to have possessed a sense of humor well calculated to dispel any priggish qualities that might have developed in such a clever youth. It was called "the enchanted lyre," and it was suspended from the ceiling by a "cord of the thickness of a goose-quill." The music appeared to proceed from a combined harp, pianoforte, and dulcimer. Wheatstone himself described it as an application of a general principle for conducting sound. A writer in the "Repository of Arts" of September, 1821, describing this instrument, foreshadowed modern broadcasting in a remarkable phrase, as follows: "Who knows but by this means the music of an opera performed at the King's Theatre may ere long be simultaneously enjoyed at Hanover Square Rooms, the City of London Tavern and even at the Horns Tavern at Kennington, the sound traveling, like gas, through snug conductors, from the main laboratory of harmony in the Haymarket to distant parts of the metropolis . . . perhaps words of speech may be susceptible of the same means of propagation."

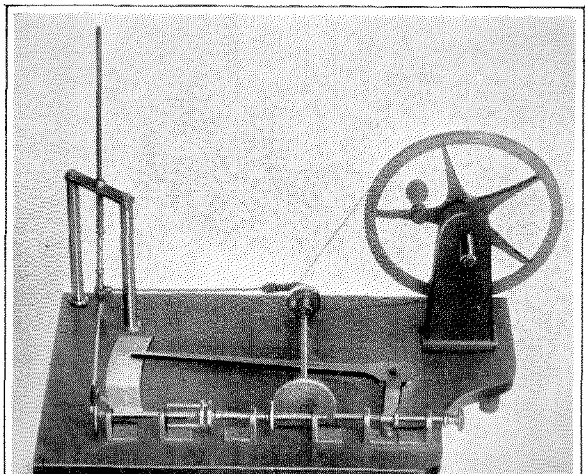


Figure 2—Adjustable Form of Kaleidophone

It is noteworthy that this instrument was exhibited in the Adelaide Gallery, afterwards the scene of his experiments on the velocity of electricity and now part of a restaurant, to the east of St. Martin's Church, London.

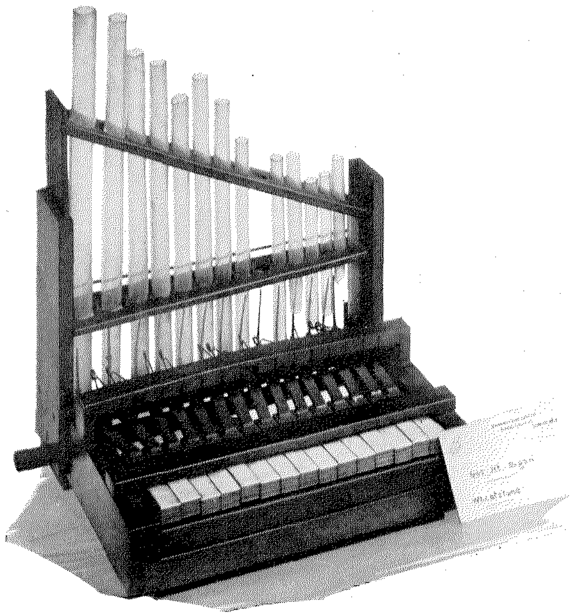


Figure 3—Gas-jet Organ

His early success with this instrument, the special features of which probably were the work of his own hands, must have been a source of great encouragement to him; for the inspirations of the physicist begin at the finger-tips, and the first victory never loses the charm that prompts renewed effort. There is evidence also that direction was given early to his scientific work by his comprehension of the importance of the undulatory theory of light propounded by Thomas Young (1773–1829). This was "the central thread of common sense" upon which the "pearls of analytical research" were strung. His collected papers indicate how firm was his grasp of the meaning of wave-motion, and his researches show with what ease he was able thereby to transfer his ideas from acoustics to optics, and rod—similar to the outlines obtained with a modern cathode-ray oscillograph. Figure 1 shows his model representing wave-motion. It consists of a frame upon which is arranged a series of bent-wire levers terminated by white

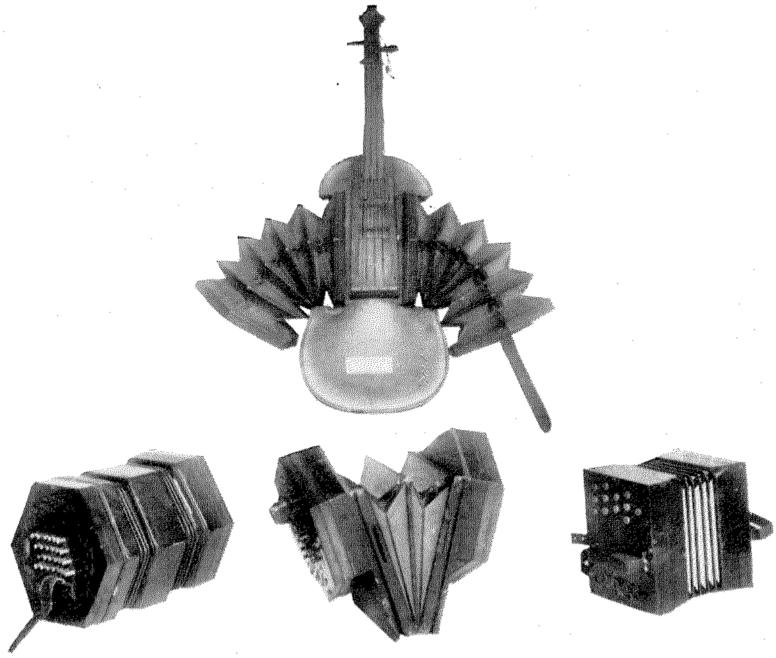


Figure 4---Concertinas and Concertina-fiddle

from optics to electricity. To realise the measure of his early appreciation it should be remembered that his first scientific paper was published in 1823, at a time when, with his brother, he was engaged in the manufacture and sale of musical instruments in London. The reward of his subsequent labours was of a kind that gave him increased facilities for extending his researches. In 1834 he was appointed Professor of Experimental Philosophy at King's College, and in January, 1836, he was elected a Fellow of the Royal Society of London.

As an indication of the general trend of his ideas, there is his memoir on Chladni's figures, and his invention about the year 1828, of the "Kaleidophone"—a simple device for combining two harmonic motions. The Kaleidophone was a steel rod of oblong section, fitted rigidly at its lower end into a heavy base-block, and provided at the top with a white bead. When displaced and suddenly released, the bead traced a curved path—determined by the respective periods and phases of the two motions of the rectangular beads, and operated by sliding wooden templates cut to the form of waves. The lowest curve is permanently fixed; the upper two curves are modified in phase respectively by the movement of the sliders.

Figure 2 represents his adjustable form of Kaleidophone. It displays Wheatstone's skill in the design of mechanical gearing. The vertical rod is held near its middle point by a ball-and-socket joint. The driving-wheel causes the horizontal transverse shaft to rotate, and motion from this shaft is transferred through a friction-disc to a lateral shaft. The position of the driven-disc on this lateral shaft can be varied by turning a milled-head at the end of that shaft, and the difference in length is taken up by a sliding clutch. Harmonic motion is thus communicated through eccentrics to the lower end of the vertical rod.

In Figure 3 is seen Wheatstone's gas-jet organ, consisting of a group of glass tubes and gas-jets operated by a key-board. The apparatus has deteriorated with age, but there is no doubt that it consisted of a horizontal supply-pipe into which vertical jets were fitted, one to each glass tube, and that the glass tubes were free to move up or down. The keys, probably, were arranged to lift the pipes with respect to the jets to different heights, for "tuning" purposes. It may be supposed that this apparatus was associated with his work in 1828, with reference to resonance in air columns.

The next ten years of his life was a period of transition from research in acoustics to research in optics. Some of his triumphs up to this turning point in his career may be recalled by examining Figures 4 and 5. The English concertina was invented and patented by Charles Wheatstone in 1829. The instruments to the right and left in Figure 4 are marked "By Her Majesty's Letters Patent, Wheatstone & Co., Inventors, 20 Conduit Street, London." As Queen Victoria was not on the throne in 1829, these must not be regarded as Wheatstone's original concertinas. The concertina-fiddle, also shown in Figure 4, is provided with four longitudinal slots, near the bridge, one below each string, which were set into vibration after the manner of an aeolian harp. Figure 5 is an illustration of Wheatstone's original table-concertina, with foot-bellows and keys for finger ma-

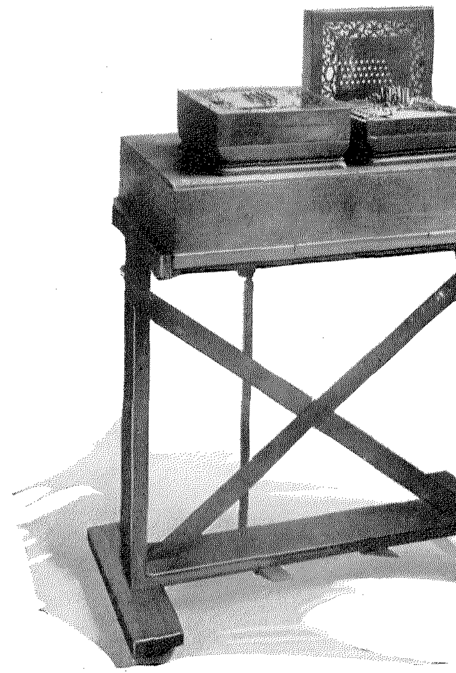


Figure 5—Table Concertina

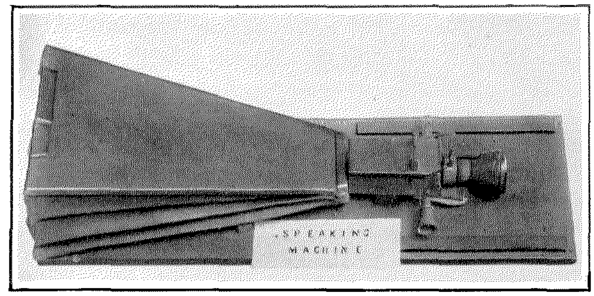


Figure 6—Speaking Machine

nipulation. Figure 6 is his famous "Speaking Machine." This consists of hand-operated bellows on the left, and a complex resonator on the right. The right hand is placed over the trumpet shaped orifice or "mouth," with varying degrees of movement or pressure. Above the "mouth" are seen two tubular "nostrils," and below the mouthpiece is a small yielding resonator resembling bellows. It was a modification of De Kempelen's machine (1783). This subject was dealt with by Wheatstone at the British Association in 1835 in his paper "On the Attempts which have been made to imitate Human Speech by Mechanical Means." He wrote also a remarkable article on the history of such devices, in the London and Westminster Review of October, 1837, concluding with the prediction of Sir David Brewster: "We have no doubt that before another century is completed, a talking and a singing machine will be numbered among the conquests of science."

If there were no other record of his genius as a research worker than his paper written in 1835 on "The Prismatic Analysis of Electric Light," his fame would have been perpetuated; for he there announced the existence of bright lines in the spectrum emitted by the incandescent vapour of metals volatilised by the heat of an electric discharge—a mode of discriminating metallic bodies more readily than that of chemical examination. Thus he laid the foundations of spectrum analysis and was an early worker at emission phenomena.

Figure 7 is an example of Wheatstone's polar clock. It depends for its operation upon a discovery by Sir David Brewster that the plane of polarisation of the sky is always 90 degrees from the sun. The instrument contains a double-image prism and a thin plate of selenite enclosed in a tube placed parallel to the earth's axis. When the prism—which carries an index traversing a circular arc marked with the hours—is turned round until no colour is perceived, the index points to the time of day.

In 1838 he wrote on binocular vision and produced the reflecting stereoscope, embodying

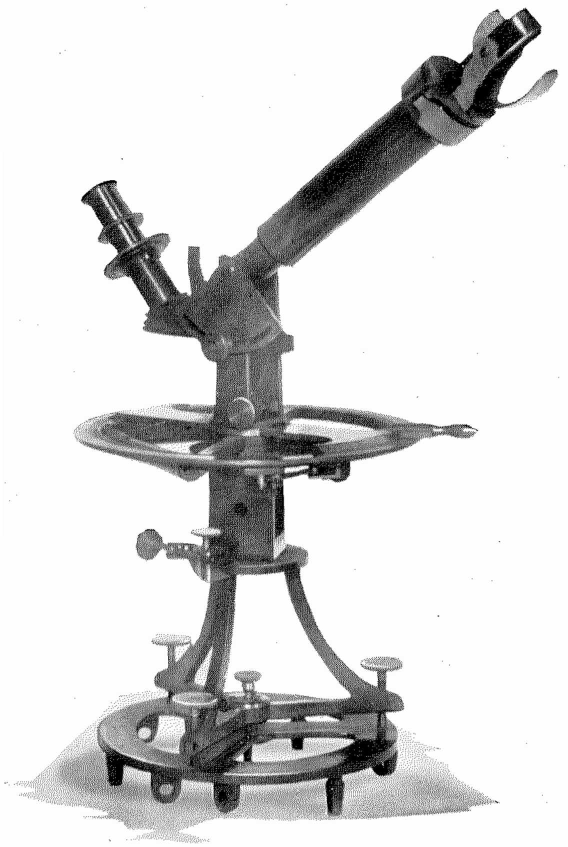


Figure 7—Polar Clock

the principle that the notion of solidity in vision depends upon the mental superposition of two pictures of the same object in dissimilar perspectives. Brewster subsequently used for this purpose the wedge-shaped segments of large lenses, in which the lens and prism arrangement due also to Wheatstone were combined. In 1858 Wheatstone extended this research, and thereby wove the threads of his early achievements in acoustics and optics into the fabric of his later success in telegraphy. Wheatstone was knighted in 1868, following upon the success of his automatic telegraph.

"Wheatstone's Bridge" was invented by Samuel Hunter Christie (1784-1865). In his Bakerian Lecture (1843) Wheatstone described it as "The Differential Resistance Measurer," and he leaves no doubt for posterity to resolve concerning its orgin. He says: "Mr. Christie in his 'Experimental determination of the Laws of Magneto-Electric Induction' printed in the Philosophical Transactions of the Royal Society for 1833, has described a differential arrangement of which the principle is the same as that on which the instruments described in this section have been devised. To Mr. Christie must, therefore, be attributed the first idea of this useful and accurate method of measuring resistances."

Figure 8, which illustrates the original in the King's College Museum, is self-explanatory, except for the small lever attachment fitted to the upper middle terminal. This was used for making a fine adjustment of what we should now call the "variable arm." For this purpose the lever was swung round to left or right until it made contact with one or other of the wires of the two arms shown at the top of the illustration of the bridge, and the rotation was continued until balance was obtained.

In the introduction to his Bakerian Lecture Wheatstone stated that the instruments and processes he was about to describe were all founded on the principles established by Ohm "not yet generally understood and admitted, even by many persons engaged in original research." He proceeded to show the need for a

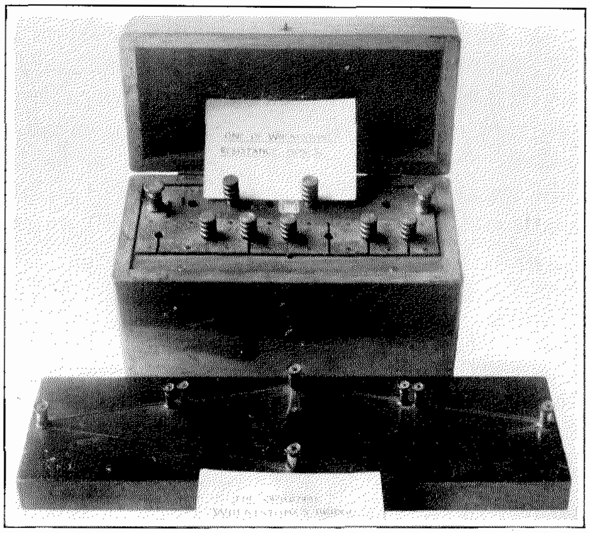


Figure 8—Wheatstone's Bridge and Resistance Box. The box is marked "Miles" near the first plug-hole on the left front.

correct standard of resistance; he adopted for his unit the resistance of a copper wire one foot in length and weighing 100 grains, and he stated the diameter as 0.071 of an inch. One of the original resistance boxes in the King's College Collection (Figure 8) is marked in "Miles"—thus adumbrating the Mile of Standard Cable. At the same time, he gave an account of "the differential galvanometer proposed by M. Becquerel." This, which in a later generation became an instrument of precision, in Wheatstone's day presented constructional difficulties. It is sufficient here to note its comparative antiquity, its supersession in 1843 by the bridge, and the association of the differential-galvanometer principle and the bridge principle as alternatives in the development of duplex telegraphy by Gintl (1853), Stearns, and others.

Wheatstone's generous and unqualified ascription to Christie of what today would be termed the "bridge principle," is more creditable and precious than any self-seeking claim could have been. The relics here illustrated serve to remind us how rapidly Christie's idea, Ohm's law, and Wheatstone's genius, conspired to produce a practical "bridge." To see the matter in true perspective, it is only necessary to turn to the original communication by Christie in the Philosophical Transactions of the Royal Society, Volume 123, 1833. He there describes an investigation to confirm what in modern language would be called the law of change of resistance with length, material, and cross-sectional area of wires, which had been clearly stated by Ohm six years earlier. He used two forms of apparatus.

In the first form, Figure 9, two wires of equal length and of different material, usually copper

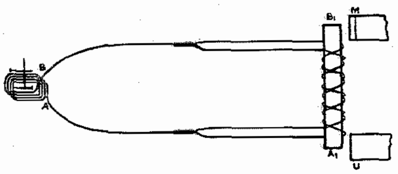


Figure 9—Christie's Differential Double Helix Resistance Balance

and iron, were wound differentially; i.e., in reversed directions, respectively, upon an iron core. The ends of the dissimilar wires were joined, and were connected to a galvanometer. The core was then placed across the poles of a large magnet. When the core was suddenly

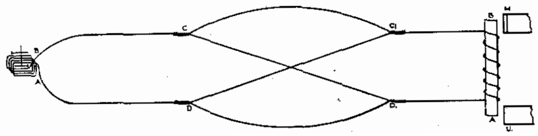


Figure 10—Christie's Single Helix Four-wire Resistance Balance

removed, the deflection, if any, of the galvanometer was observed.

In the second form the arrangement was as represented in Figure 10. Here dissimilar wires were again connected in pairs, CC^1, CD^1, and DC^1, DD^1. In Christie's own words: "On the contact of the ends of the iron cylinder with the poles of the magnet being made or broken, a current of a certain intensity being excited in the helix round the iron cylinder, became, at the points C^1D^1, the source of currents in the copper and iron wires; at the points CD, equal facilities were afforded by the wires CB, DA, for the transmission of these opposing currents to the galvanometer, where consequently, their difference might be very accurately measured. Or viewing the subject in a somewhat different light, at the points C^1D^1, two routes are presented to the current excited in the wire of the helix, one through the copper wires, the other through the iron, and the effect at the galvanometer would measure the difference in the conductivity powers of the two metals."

Again, he states: "When I first made use of the arrangement which I have described, the subject being quite new to me, I was not aware of that employed by M. Becquerel. There is some similarity in the two, but the principles on which their application depends are very different. M. Becquerel's depends upon two equal currents, in separate wires, being equally diminished by two other currents, likewise in separate wires: mine, on the effect of a current in a single wire being counteracted by an equal and opposite current in the same wire, or that the opposite electricities neutralise each other, so that no current exists in the wire of the galvanometer. It appears to me that my arrangement combines the advantages of greater simplicity and greater accuracy."

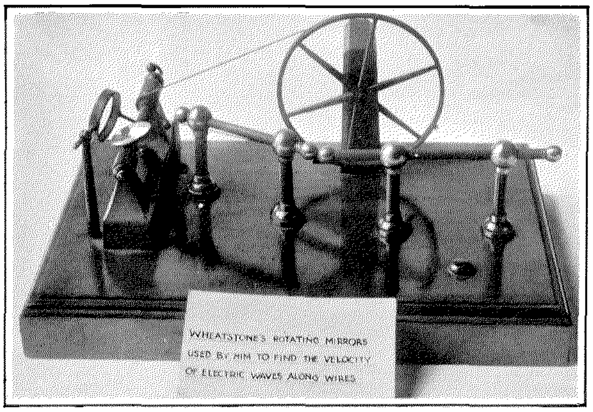


Figure 11—Spark-gap and Rotating-mirror

The dynamical method of computation adopted by Christie should be examined in detail; it illustrates the difficulties encountered by those who, in Wheatstone's phrase, had "not yet generally understood" Ohm's law, in dealing with network problems.

Wheatstone's investigations of the "Velocity of Electricity and the Duration of Electric Light" are described in the Philosophical Transactions of the Royal Society of 1834. Examples of his original pieces of apparatus with their revolving mirror, from the King's College Collection, are illustrated in Figures 11 and 12. The story of his preliminary failures and of his constant determination to overcome all obstacles in this research must be read in detail to be appreciated. Some of his experiments on the time occupied by sparks to pass through insulated wire were carried out at "the Gallery in Adelaide Street." The greatest elongation he observed of the projected image of the spark was 24 degrees, corresponding to 1/24000 second, and for the velocity through the wire he obtained "288,000 miles in a second." In this trial the mirror rotated 800 times in a second. He also investigated the rate at which an electric wave travels through a wire, by suspending half a mile of copper wire in the vaults under King's College. Three interruptions of the circuit were made at three pairs of brass knobs. He repeated this research with four miles of wire.

With reference to these experiments Oliver Heaviside long afterwards pointed out (Electrical Papers, Part II, p. 395) that Wheatstone's result: "has not been supported by any later results, which are always less than the speed of light (even in a distortionless circuit). But a reference to Wheatstone's paper on the subject will show, first, that there was confessedly a good deal of guesswork; and next, that the repeated doubling of the wire on itself made the experiment, from a modern point of view, of too complex a theory to be examined in detail, and unsuitable as a test."

There is not space here to recount the wonderful story of Wheatstone's share in the development of telegraphy. The lamentable dispute with his partner, William Fothergill Cooke, will exemplify to all time the need for definite agreements between the principals in such enterprises, and the deplorable waste of energy, time, and happiness that results from personal friction. It must suffice to state with regard to the crowning achievement that Wheatstone's contemporary, De la Rive, said, "the philosopher who was the first to contribute by his labours, as ingenious as they were persevering, in giving electric telegraphy the practical character that it now possesses is undoubtedly Mr. Wheatstone." Of the combined efforts of the partners, it was declared by the late Willoughby Smith on the occasion of the Extraordinary General Meeting of the Society of Telegraph Engineers and of Electricians held in Paris during the Exposition Internationale d'Electricité, September 21, 1881, that "no account of a practical electric telegraph had been published

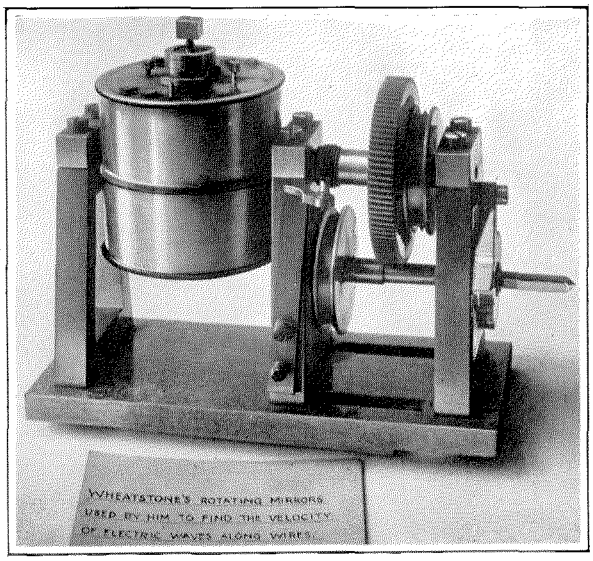


Figure 12—Rotating-mirror

prior to the date of Messrs. Cooke's and Wheatstone's patent of June, 1837."

Among the illustrations of Wheatstone's apparatus may be seen the original of his Letter Showing instrument (Figures 13-A and 13-B). The maker was Ruhmkorff, Paris. Figure 14 shows Wheatstone's Relay. A V-shaped piece of metal attached to a magnetic needle is brought—when the needle is deflected—into contact with two mercury surfaces in a divided

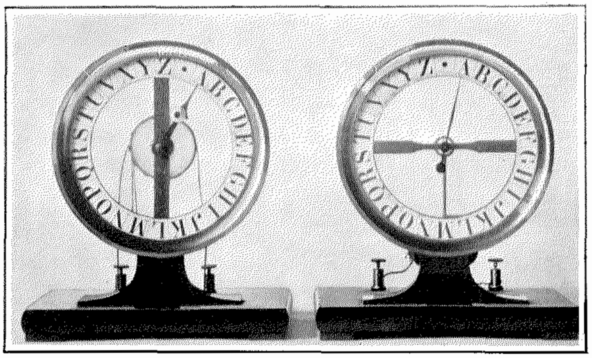


Figure 13-A—"Letter-showing Telegraph" (Front)

insulating cup. Figure 15 depicts Wheatstone's tape-puncher; Figure 16 Wheatstone's five-needle telegraph and Figure 17 Wheatstone's single-needle telegraph "sender" and "receiver."

The tale of the five-needle electric telegraph (1837) is well told by Professor J. A. Fleming

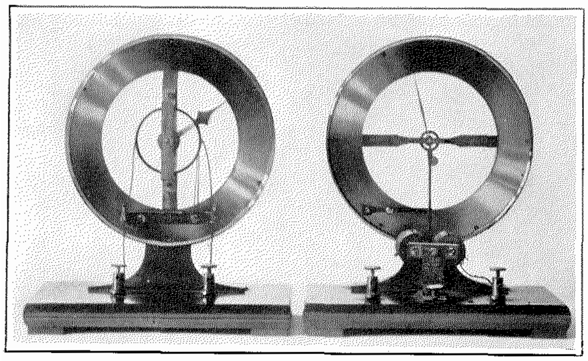


Figure 13-B—"Letter-showing Telegraph" (Back)

(Fifty years of Electricity). This telegraph was being worked between Fenchurch Street and Blackwall railway station, when three of the five dials broke down. The telegraph clerks, however, made up a code for working with the remaining two and the result was quite as good,

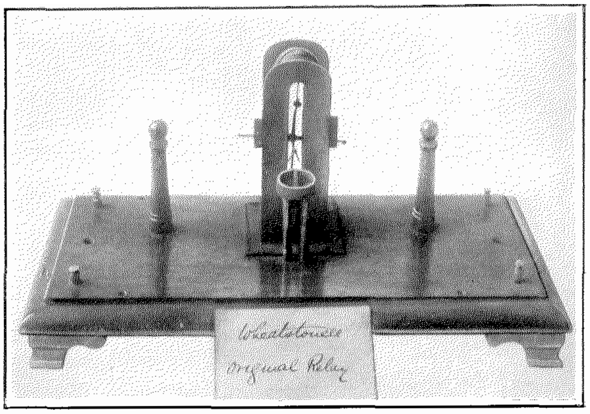


Figure 14—Original Relay

if not better, than before. Thereafter one needle was found sufficient.

Figure 18 reminds us that Wheatstone contributed to the development of the dynamo. S. P. Thompson in his treatise on the dynamo has indicated the main features of Wheatstone's part in that work. Wheatstone began his improvements in 1841, with a machine in which for the first time the armature coils were so grouped as to give a really continuous current.

In 1856 C. W. Siemens took out a provisional patent for the shuttle-wound longitudinal armature, invented by Dr. Werner Siemens. On January 17, 1867, Dr. Werner Siemens described

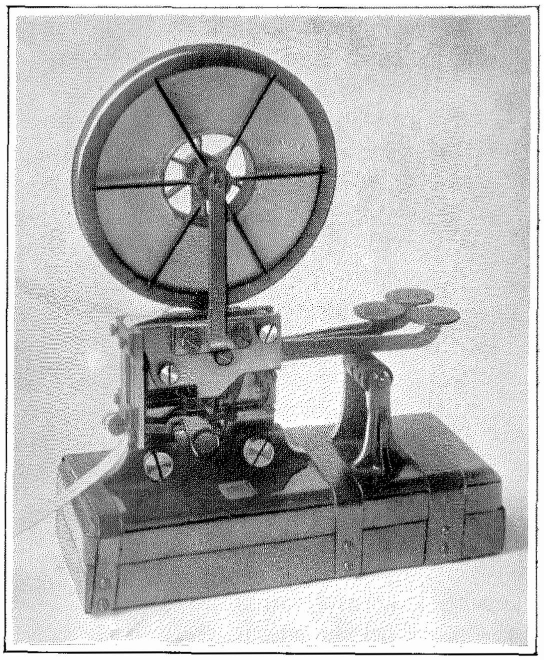


Figure 15—Tape Puncher

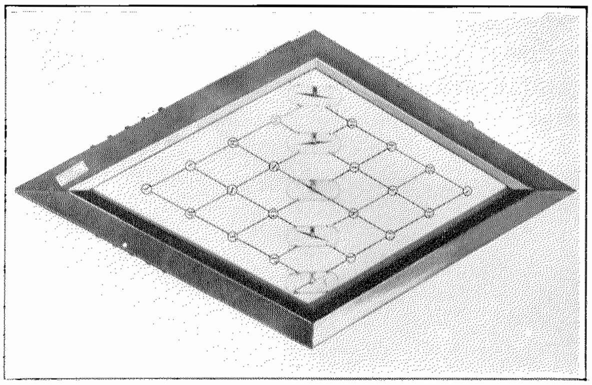


Figure 16—Five-needle Telegraph

a self-exciting dynamo in which the exciting coils were in the main circuit in series with the armature coil. On February 14, 1867, Wheatstone described to the Royal Society his invention of a similar machine in which the exciting coils were connected as a shunt. A self-exciting machine without permanent magnets had been constructed for Wheatstone by Stroh in the summer of 1866. In 1867 Ladd exhibited a self-exciting machine having two shuttle-wound armatures—a small one to excite the common field magnet, a large one to supply currents for electric light.

It is fitting that there should be found with Wheatstone's apparatus a tribute to the work of Henry. The precise history of the coils of copper strip, insulated with silk (Figure 19) cannot be ascertained, but the label, which has been attached to them for some years, declares

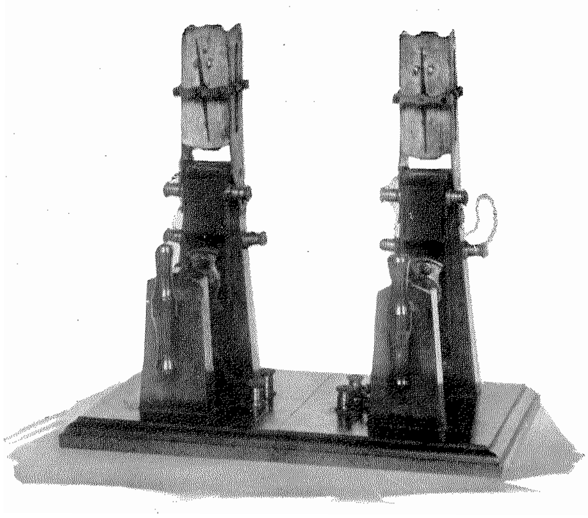


Figure 17—Single-needle Telegraph "Sender" and "Receiver"

them to have been used by Henry in his experiments on induced currents. Henry visited England in February, 1837, and met Wheatstone, Faraday, and Daniell at King's College. The three philosophers there exchanged ideas, and carried out experiments together. It is

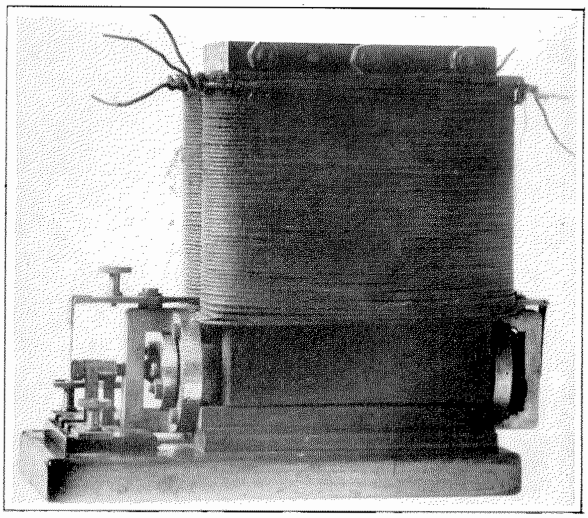


Figure 18—Wheatstone's Dynamo

possible that these coils were used by Henry in this demonstration; but whatever their origin, they recall a fellowship that made history, and a meeting which Henry in subsequent years remembered with pleasure.

The relics include two photographs, one of

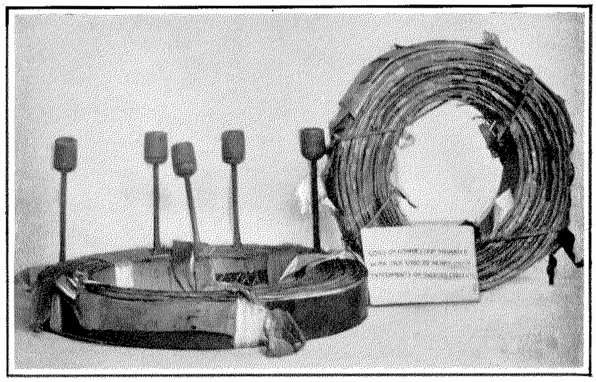


Figure 19—Coils of Copper Strip, Insulated with Silk, used by Henry in his experiments on induced currents

Wheatstone, reproduced in the frontispiece, and the other (Figure 20) of Wheatstone in a group with his friends: Faraday, Huxley, Brewster and Tyndall. In Figure 20 Wheatstone is hold-ing a Morse Key, while his companions are examining his Inkwriter, which is upon the table. The cell at the side of it appears to be a "Bunsen," but it may have been a "Daniell." It is appropriate that Wheatstone should be there amongst his peers: Faraday, the prince of experimenters; Huxley (1825-1895), the would-be engineer who became a leading biologist and the most astute controvertialist against the dogma of his day; Brewster (1781-1868), the poet, preacher, physicist, the inventor of the Kaleidoscope, the biographer of Newton, and the writer of three hundred and fifteen papers on scientific subjects; and Tyndall (1820-1893), the Irish National-school boy who became an engineer, a student in Germany, a professor of natural philosophy at the Royal Institution, a good sportsman, a colleague of Faraday, a physicist of the first rank, who made the Alps his own, and a writer unexcelled in the whole range of scientific literature. With the exception of Brewster, none of the group received what may be called systematic education, all were ardent research workers, all became Fellows of the Royal Society, all were distinguished writers. A man is known by his friends, and by these we may know Charles Wheatstone.

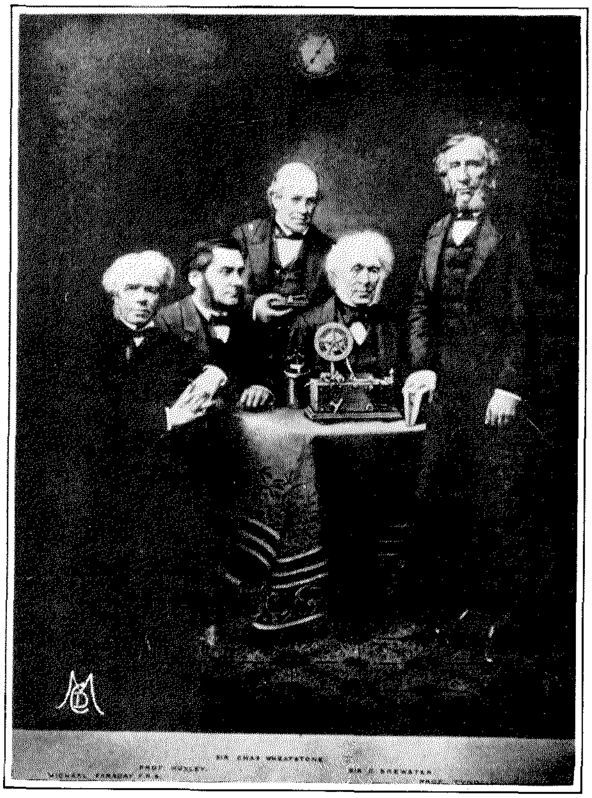


Figure 20—Michael Faraday, Professor Huxley, Sir Charles Wheatstone, Sir David Brewster and Professor Tyndall

Methods of Introducing Automatic Telephony to the Public

By A. SANDMEIER

Member of the Direction Generale des Telephones of the Swiss Government at Berne

THE precautions taken by the Swiss Government to instruct the public in Basle before conversion to automatic telephony were amply justified by the very successful cut-over of the Basle Rotary System automatic office on the night of Saturday, September 27, 1926. Among other means adopted to popularise the system was the exhibition at the Swiss Samples' Fair of a small model of a standard installation, capable of demonstrating to prospective subscribers the methods of operation and the advantages of the system. The present is an opportune time for considering, in the light of this experience, the general problem of how to dispose of prejudices that the public at large may entertain towards automatic telephone exchange systems, and how to give assurance that such systems are advantageous.

Necessity of Instructing the Public

With the advance of technical development in automatic telephony, objections and fears are rapidly and completely disappearing. It is found to be perfectly adapted to the needs of the present time when economy and efficiency are essential. Experience shows that subscribers, when the installation is completed and the cut-over successful, quickly become accustomed to the new system and convinced of its advantages. They lose altogether the habit of making use of the manual system. Individuals have their own preferences but the new system can give satisfaction to all tastes. Wherever the manual system is not operating satisfactorily, the automatic telephone is more readily, even eagerly, accepted. It is necessary in this case to recognise a psychological condition. On the one hand, subscribers are dissatisfied with a manual system which has become inadequate, on the other hand, with the new system they become accustomed to the consequences of wrong manipulation on their part. Hence, though the public are well disposed towards the novelty, it is necessary to instruct them when introducing the automatic system, in order that they may learn how to make judicious use of the apparatus. Inasmuch as defective installations and faulty traffic methods may cause an unfavorable reaction on the part of subscribers, the primary requirement when installing automatic systems is that the equipment and operations shall be perfect. Initial circumstances will exercise a lasting influence on the attitude of subscribers towards the exchange.

A system that has been inaugurated successfully is likely, from the beginning, to increase the faith of the subscribers in the new means of communication. If it works in a defective way, however, the user fails to acquire confidence in the mechanism and tends to consider it responsible for all errors, including those due to his own failings.

After a project has been carefully prepared, steps must be taken to ensure that subscribers will become familiar, from the beginning, with the new installations. They must be taught to understand the nature, the object, and the common-sense reason for the dispositions in which they are particularly concerned. There is need, therefore, for a kind of introductory course to initiate telephone users into making the manipulations and in observing the signals employed in the automatic system. The use of the dial requires collaboration with subscribers. If, for example, it is contemplated to incorporate automatic rural exchanges within a system of automatic city exchanges—in other words, to create a group of networks consisting of city exchanges and rural exchanges within a whole territory—subscribers already partly instructed will facilitate the general initiation, and it would be useful to complete their knowledge.

The public remembers the inconvenience caused through the conversion of large capacity exchanges of the local battery system to the central battery system. It should be made clear that the putting into service of automatic exchanges is still more involved, owing to the inherent technical difficulties and the ever growing demands made by subscribers upon the telephone service. It should be pointed out also

1. Please consult the most recent Subscribers Directory to ascertain correct call number of the desired subscriber.

2. Lift receiver to the ear and await dial tone. Dial tone is the signal for "exchange free."

3. Now set the exchange code letters and numbers on the dial with the finger disc.

Read or set telephone numbers from left to right; that is, first exchange code letters (S for Safran, B for Birsig), then thousands, hundreds, tens and units figures.

Example: To call the subscriber "Safran 5789."

Lift receiver to the ear, await dial tone. Insert finger in the opening in the disc marked "S." Turn disc in right direction up to the finger stop. Withdraw finger and await for the finger disc to come to rest. Insert finger in opening 5. Dial further up to the finger stop and let it go. Then set in exactly the same manner the figures 7, 8 and 9.

The course of the disc is not to be accelerated or retarded by catching hold of the dial.

When the number is finally sent, then the desired connection will be completed by the automatic exchange.

4. If ringing tone is heard in the receiver (a short buzz tone) then the subscriber is free. The called subscriber's bell rings at intervals of 10 seconds. The caller listens to control this call. If no one answers within one minute, then hang up the receiver and make the call again later.

5. If the busy signal is heard in the receiver (a buzz tone in uniform rhythm) then the called subscriber is engaged. Hang up the receiver at once. The call can be repeated a few minutes later.

6. If, on setting the number, an error has been made in dialing, or if a new connection is desired, then press the switchhook for one second in downward direction, await the dial tone signal and set the number again correctly on the dial.

7. If conversation is proceeding, the switchhook must not be moved and the finger disc must not be turned.

8. For connections with the following service points, one should select:*

1. Enquiry for numbers which are not in the directory, and for obtaining emergency calls....No. 11
2. Fault position for announcing disturbances on the apparatus, on lines or in the exchange....No. 12
3. Telephone Service . . . Ordering Calls.....No. 14
4. Toll Service . . . for enquiries as to the cost of toll calls....No. 15
5. Supervisory Toll Exchange for complaints regarding calls....No. 19
6. Telegram Reception Service—for delivering telegrams by 'phone....No. 10

*See also beginning of Subscribers' Directory under heading "Instructions for the use of the Telephone," Section D

Figure 1—Translation of Instruction for the Use of Automatic Telephone Stations

that the new system amply meets all requirements.

Subscribers at first are disinclined to perform the slight supplementary work demanded by automatic telephony, but the curious fact emerges that the critical adapt themselves the quickest to the new circumstances.

Modern commercial experience in many directions compels the public to appreciate the fact that the advantages to be derived from new methods and devices frequently can be gained only as the result of self-training, and that the effort is worth while. To this precept automatic telephony offers no exception.

Means of Informing Subscribers

Before automatic exchanges are put into service, the Administration of Posts and Telegraphs begins propaganda in the Press, acquires the collaboration of editors and invites their representatives to visit the new installations and to attend a conference on the subject. The collaboration of the Press is very valuable. Besides accepting for publication the communications forwarded by the Administration, the editors examine and test communications they receive from subscribers and by so doing save the Administration a great deal of trouble. When re-grouping subscribers' numbers, which is effected generally a year before placing the exchanges in operation, this collaboration proves indispensable.

Communications and instructions sent directly to subscribers are of no less moment. Addressing subscribers directly is in accordance with commercial principles, but experience has shown that attention is not always paid to communications of this kind. It often happens that they are not circulated and are, therefore, not brought to the knowledge of the persons who make most use of the telephone and who consequently have occasion frequently to establish exchange connections. In consequence of this neglect, users make omissions in strange contrast to the severe requirements they place upon the telephone service.

Communications to subscribers should urge them to submit their complaints directly and at once to the competent authority, instead of publishing in newspapers complaints concerning sporadic incidents. When the telephone service is a State monopoly, subscribers find pleasure in causing public discussions calling the Press to the rescue. This is not always to be discountenanced, but the public should be taught to realise that it is not the most effective procedure, and that there is a better way of arriving at efficiency.

Figure 1 is a translation, with schematic of the subscriber's dial omitted, of an "Instruction for the Use of Automatic Telephone Stations" distributed to the Basle subscribers before the inauguration of the automatic exchange. As soon as the sets with dials are installed, subscribers are invited to make trials. Accordingly the exchange asks them to manipulate the dial and to dial certain numbers; furthermore, it is recommended that they observe the signals such as "exchange free," "dialing tone," "ringing tone," "busy tone," etc. With this in view, operators call subscribers from suitable test positions controlling different dials, send the above mentioned signals, and direct attention to the differences by which they are characterised. On these occasions the exchange can rectify wrong ideas and can give explanations where necessary.

Subscribers at first are apt to be embarrassed by the signals. Not only do they forget sometimes how the signal "exchange free" manifests itself, but they have difficulty in discriminating the ringing tone from the busy tone. If these signals are not well distinguished both as regards pitch and intensity of sound, they are easily confounded. Subscribers must learn to decide for themselves, on hearing these signals, whether they should restore their telephone immediately (busy tone) or after a short waiting time (ringing tone repeated at regular intervals being an indication that the subscriber has not answered). It is useful, therefore, to acquaint the subscriber with the busy tone at least, before the automatic system is inaugurated. For example, beginning on an agreed date, the operator may refrain from notifying the subscriber vocally when the desired line is busy and from inform-

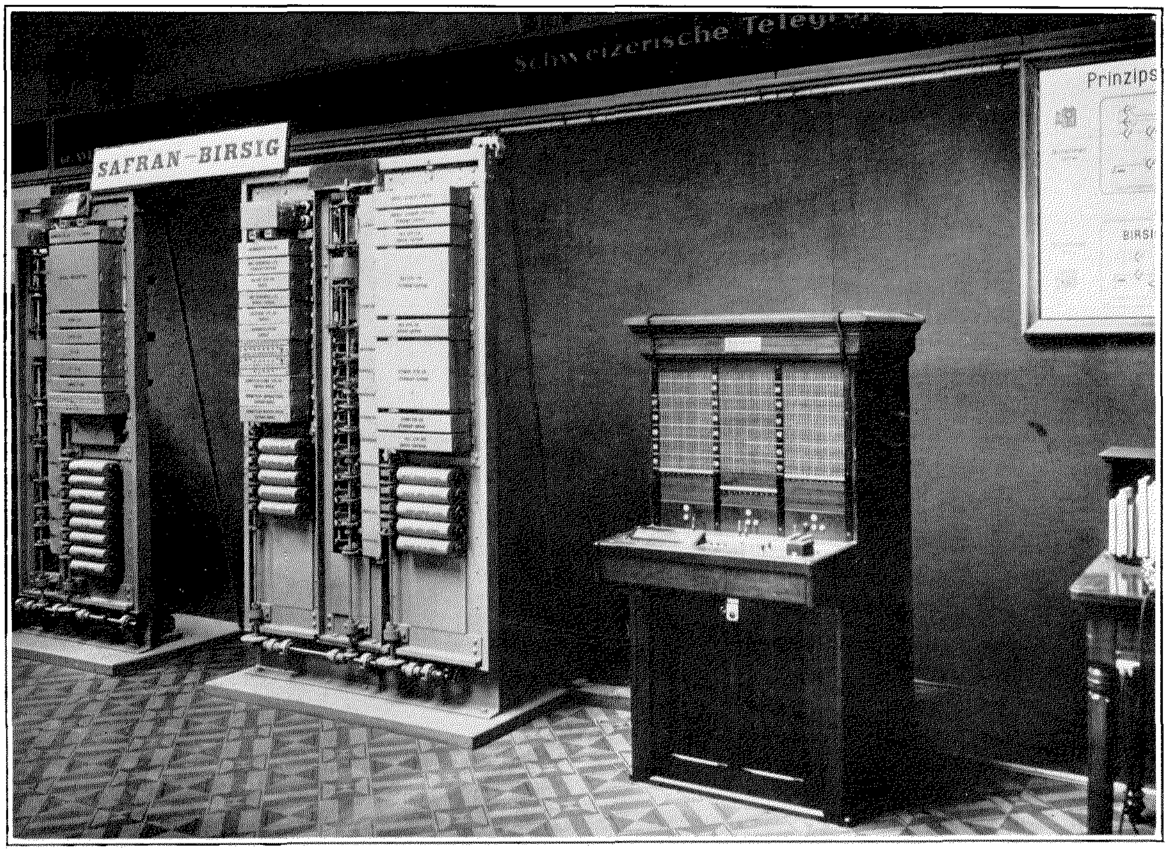


Figure 2—Model of 7-A Machine Switching Equipment, Rotary System, at Basle, and Manual Board at Birsig

ing him that he will be called again when the desired connection is free; instead, she may transmit the busy tone to the subscriber.

At Zurich arrangements have been made such that by the middle of 1927 four full automatic Rotary System exchanges supplied by the Berne Branch of the Bell Telephone Manufacturing Company, an Associated Company of the International Standard Electric Corporation, will be in operation. These are called "Hottingen," "Selnau," "Uto" and "Limmat;" the network also includes five sub-exchanges and will have a total initial capacity of 27,000 lines, which probably will be reached by 1930. Considering the severe requirements as regards quality that the Zurich subscribers place upon the telephone service, and the measures that the Administration contemplates for the inauguration of the new installation, the conversion to automatic working of the Selnau central battery exchange of 9,000 lines capacity, represents a technical problem of considerable magnitude.

Experience gained at the Samples' Fair at Basle has proved that demonstrations of automatic telephony are of great advantage. So far as Zurich is concerned it has been suggested that propaganda work be conducted at Kinemas and by broadcasting.

The apparatus for the Basle demonstration is illustrated in Figures 2 and 3. The contract stipulated that for this purpose the Bell Telephone Manufacturing Company, Berne, should deliver a demonstration model with the material for the two exchanges at Basle; i.e., "Safran" and "Birsig."

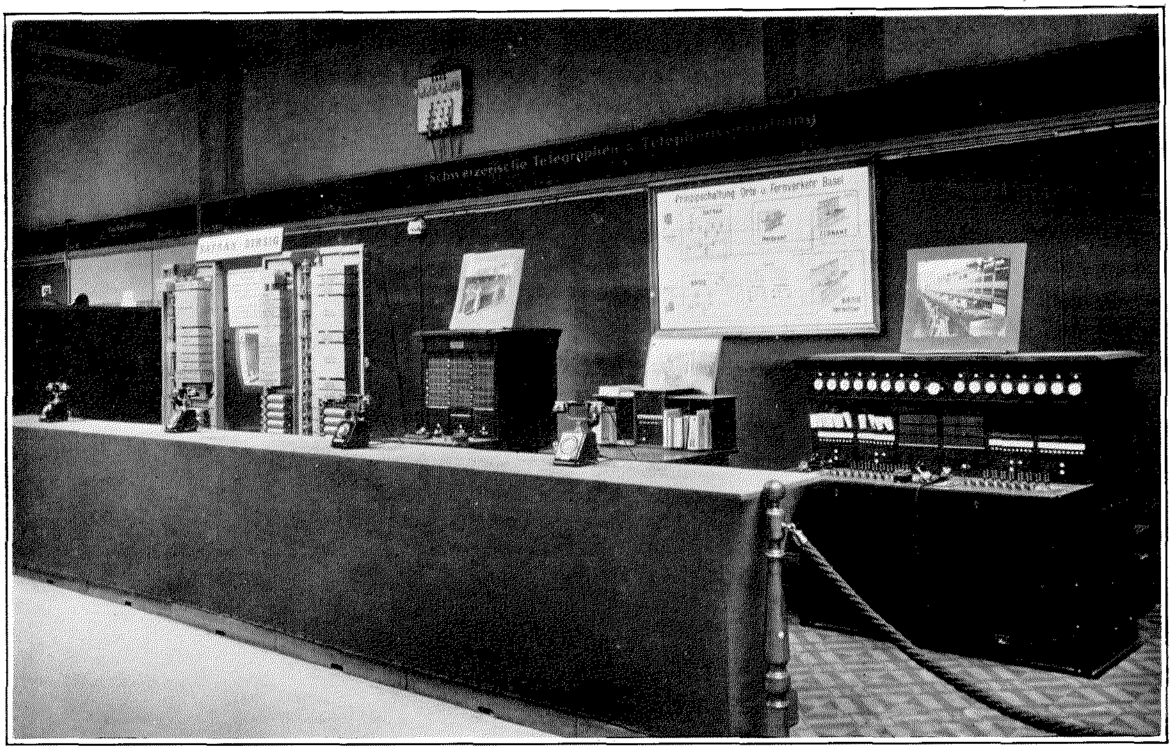


Figure 3—Model of 7-A Machine Switching Equipment at Basle, and Recording and Toll Switchboards at Safran

In order to give visitors a general idea of the actual exchanges, corresponding photographs (see Figures 2 and 3) of the apparatus under construction were placed on top of the different parts of the model. Between the bays of the apparatus bearing the inscription "Safran-Birsig" (Figure 3) was placed a view of the rows of switchracks of the Safran exchange. Above the central switchboard which represents the manual operators' positions at the Birsig exchange, a photograph showed the row of switchboards actually existing in this exchange. Above the recording position was fixed the photograph of the recording switchboards with the mechanical ticket belt carriers and pneumatic tube distributors. Finally above the right toll switchboard, one of the rows of toll switchboards of Basle was illustrated.

Before studying the fundamental diagram of the model (Figure 4), it is desirable briefly to examine the guiding motives for the installation of the new exchanges. Specialists are rather attracted to the novelties introduced in the exchanges situated beyond our frontiers; for example, the exchanges of large cities like London or Paris. The case of Basle itself presents some interest owing to the fact that the service in this city has always worked under good conditions and that the subscribers exact much from the telephone. When the required conditions are fulfilled, the introduction of new traffic methods is instructive in many respects, particularly if they cause the rental revenue of the undertaking to increase.

The traffic system which was put in practice in Basle and which comprised a single central battery office, had to be transformed completely because the maximum capacity of 9,600 lines was attained. It was necessary to install a second exchange and, consequently, to adopt the system of multi-exchanges.

The distribution of subscribers lines, already connected, or to be added, in the city area, was such that the formation of two separate cable networks was not found to be advantageous. Consequently the second exchange was accommodated in the same building as the existing exchange. It was necessary to transform the building, but the expenses have been much lower than those which would have been required for the purchase of ground and the construction of a special building on another site. By the adoption of this solution, Basle will possess two exchanges of 8,500-9,000 lines each, which will be sufficient for ten to twenty years. Furthermore, within a radius of 5 kilometers of the main exchanges, a few automatic sub-exchanges of a maximum capacity of 1,000 subscribers each are to be installed. When the decision was reached to install a second exchange in the same building as the old exchange, provision had to be made for:

1. A system of multi-exchanges with automatic operation.
2. The continuance of the manual exchange equipped with central battery which is still in perfect working condition.
3. Economical operation, keeping in mind the maintenance of the manual exchange, and the handling of calls between exchanges.

Condition 1 has been fulfilled, providing for the conversion to automatic of the Safran exchange. As regards conditions 2 and 3, they have been met, in the first instance by connecting the subscribers who make a great number of calls, to the automatic exchange and those who use the telephone less frequently to the manual exchange Birsig; then by assigning junction traffic from Birsig to Safran to the "A" operators' positions of Birsig; and lastly by installing operators' positions with visual indication of the numbers (call indicator positions) for calls from Safran to Birsig. An attempt was made to improve the efficiency, in particular of the Birsig exchange, by providing it with an automatic system for distribution of calls, which gives this exchange a semi-automatic character, although this term implies something more complete. Furthermore, the routing of the toll calls destined for the Safran exchange had to be done automatically, from the toll operators' positions, over toll final selectors. Finally, it was found necessary in the Safran and Birsig exchanges to design the circuits for the repeated metering of suburban connections. The project submitted by the Bell Telephone Manufacturing Company was realised. All the above mentioned installations were cut into service in the autumn of 1926.

The following explanations will enable the operation of the demonstration model illustrated in Figure 4 to be understood.

A connection Safran-Birsig, for example, is effected as follows:

Subscriber's set Safran, 1st line finder I A.S., 2nd line finder II A.S. (forming part of the cord circuit), register chooser R.S., register group selector G.W., and thence to calling plug and via finder S.S. and register R.O. to the call indicator lamp box of the Birsig position.

A call Birsig-Safran is routed as follows:

Subscriber's set Birsig—link circuit; i.e., line finder A.S. and cord finder S.S. to a free single plug ended cord circuit of a disengaged call distributing position. The operator to whom a call has thus been directed hears in her receiver a short tone and identifies the call by means of the flashing of the lamp corresponding to the plug. She asks the subscriber the desired number. As previously stated, the same operator has a key-set by means of which she mechanisms as the actual exchange and its future study by the operating personnel, therefore, should prove advantageous.

Two experienced operators were charged with presenting the installation to interested visitors at the Fair. At certain times, technical em-

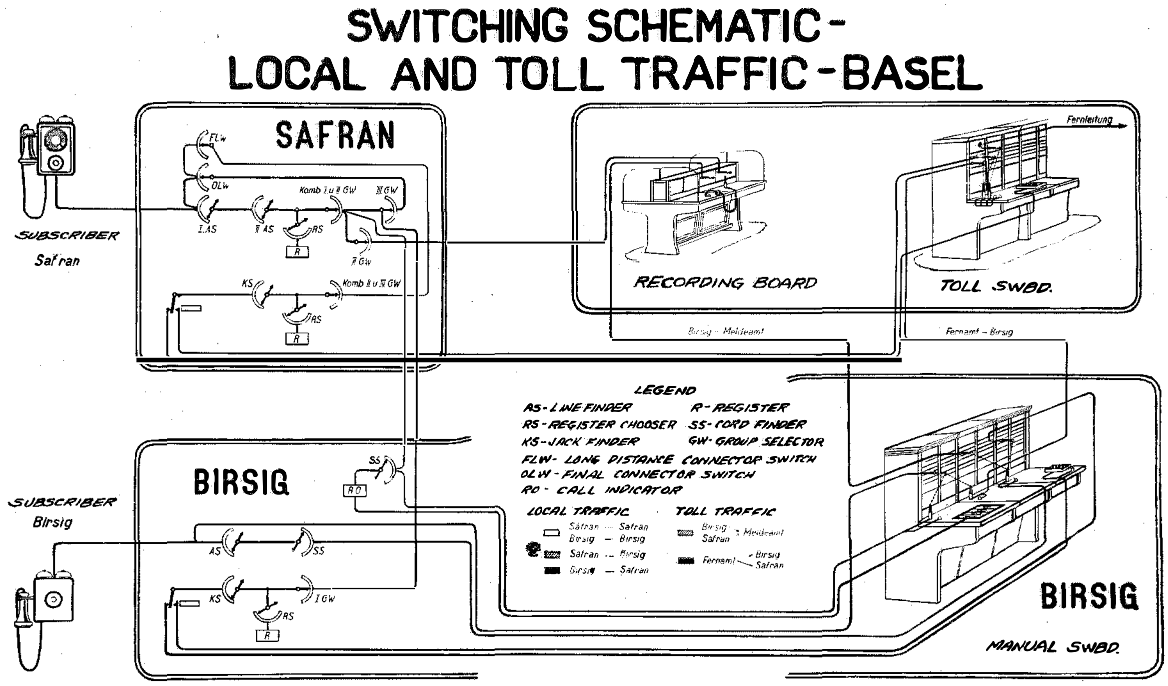


Figure 4—Diagram of Connections of Demonstration Model for Basle Area

can direct to the switching apparatus the calls destined for the automatic exchange Safran without the intervention of a second operator.

The connection Birsig-Safran is continued as follows:

Plug, with the lamp flashing, inserted in jack, on the one side over the back contact of relay in the Birsig diagram and on the other side over the key-set and front contact of relay to jack finder K.S. of link circuit—register finder R.S., register R—then, first group selector I G.W.—third group selector III G.W. of Safran diagram —final selector O.L.W. for local calls—Safran subscriber's line, etc.

In the course of the demonstrations held with the small model during the Samples' Fair, the visitors were shown how all phases of the connections they have to establish, most frequently from thier own sets, succeed one another.

The model employs the same circuits and

ployees also attended the demonstrations. There is not the slightest doubt that such an exhibition contributed powerfully towards making the Basle residents familiar with the manipulations to be effected and the instructions to be observed by automatic telephone users. Many visitors also made it a point to establish the connections themselves. In demonstrating by means of the model the different phases of the System's operation, it was possible first to give an idea of the effects of false calls—which can start alarm signals—and afterwards to show what happens when the subscriber does not wait for the dialing tone; when the caller improperly keeps moving the switchhook of the apparatus up and down, or when he dials the wrong number, etc. It has been possible also to prove the necessity for restoring the receiver promptly when the line is busy or when the subscriber does not answer. The demonstration relating to toll calls and to registering of calls was also instructive.

It was obvious that the majority of the spectators contented themselves merely with looking at the installation that was demonstrated. Others, on the contrary, followed the explanations with the greatest attention.

Service Observations Concerning the Utilisation of the New Operating System by Subscribers

Under this title, it is proposed to show how necessary it is, even after the cut-over, to continue the instruction of subscribers and to try thereby to secure a good working service with their intelligent collaboration.

To make things plain for the subscribers, the Press was resorted to and, furthermore, communications were forwarded to each subscriber; i.e., instructions in accordance with Figure 1. Subscribers from Zurich had not received such complete instructions as those from Basle. They already knew the busy tone and the ringing tone, however, for they had heard these when the semi-automatic system existed. The first column of Table I contains the percentage of false manipulations and irregularities on the part of subscribers who, after their calls were handled through a semi-automatic system, were connected to a full automatic system. The second column contains, for comparison, corresponding values relating to subscribers who have for some time been on full automatic installations. A total of 18 per cent compared with a total of 5 per cent distinctly indicates to what extent subscribers, owing to their own faults, lose the benefit of the advantages a good working telephone service offers.

TABLE I

Results of Service Observations, Subscribers of Hottingen and Limmat Exchanges, Zurich

False manipulations and irregularities on the part of subscribers whose calls are attended to by a full automatic exchange	Percentage of faults in relation to the total number of observed connections		
	1. Subscribers connected only a short time to an automatic exchange (900 connections observed) %		2. Subscribers connected for a relatively long time to an automatic exchange (12,000 connections observed) %
1. The subscriber does not observe the dialing tone and moves the switchhook up and down.	0.22		....
2. The subscriber dials, but forgets to complete a call, restoring the receiver afterwards.	0.22		....
3. The subscriber hears the dialing tone, but does not dial the number; he restores his receiver after a moment.	6.89		3.13
4. The subscriber dials his number before hearing the dialing tone.	1.45		0.18
5. The subscriber forgets to dial "Zero" at the beginning of the number; e.g., S. 715 instead of S. 0715.	0.22	7.33 (items 5–9)	1.32 (items 5–9)
6. The subscriber does not dial code letter of the exchange.	0.44		
7. The subscriber only dials 4 digits, in this case it has not been possible to verify whether it is the "Zero" which has been omitted or the code letter of the exchange.	4.78		
8. The subscriber only dials 3 digits.	1.11		
9. The subscriber only dials 2 digits.	0.78		
10. The subscriber dials a total of 6 digits.	1.00		....
11. The subscriber has dialed 9 digits.	0.11		....
12. In dialing, the subscriber confounds the tenths with the units; e.g., 71 instead of 17.	0.44		....
13. The subscriber dials false code letters.	0.33		....
Total of wrong calls and false connections for which the subscriber is incontestably responsible.	about 18%		about 5%

In Table I will be found the results obtained while observing the subscribers of the Zurich exchanges, Hottingen and Limmat. Important groups of subscribers, who formerly were connected to the semi-automatic exchange of Hottingen, were connected partly to the automatic exchange Hottingen and partly to the Limmat exchange.

Even in the case of an exchange designed and tested carefully for a given capacity, a certain degree of confusion is always brought about in the busiest hours (peak load) at the beginning of its operation. The fault lies undeniably with the subscribers as shown in Table I. The data of column 1 refer to a period of zero to eight days after the cut-over. They thus correspond approximately to the peak of the fault curve which, after about two months, reaches the value of column 2. The high figure of faults expressed in percentage in column 1, proves clearly that during the first hours and the first days that follow the introduction of the system, all the positions in the exchange where the observation of the traffic can be made, should have enough personnel to help the subscribers.

When the new exchanges have been in operation for some time and it has been ascertained through the service observation that conditions have again become normal, it is necessary to pay great attention to the opinion of subscribers regarding the telephone service. During the inauguration of the new exchange and the critical period following it, the opinion of the subscribers about the telephone service may be unfavourable. The improvement that the new system brings, as a rule, is criticised and even contested in spite of the fact that the service of the exchange may be considered satisfactory. Once the subscribers get accustomed to the new installation with consequent improvement in the service rendered, this opinion manifested by criticism and occasional complaints is at variance more and more with the actual facts.

It is precisely this time that is chosen by the Swiss Telephone offices to consult the subscribers by means of circulars. The front of the circular letter is reserved for the request and the back for the answer. The subscribers are asked whether they are content with the telephone service and whether the service has given them satisfaction lately. Thus they are compelled to discriminate between the past and present—which is of moment.

It can be concluded from the subsequent attitude of the subscribers that the advantage of such consultations is great. They are favourably influenced because these consultations convey the impression that the administrative body is interested in their opinions.

Table II contains a summary of subscribers' replies.

TABLE II

Summary of Subscribers' Opinions of the Telephone Service

Consultation of 100 Subscribers of the Sub-exchange "Hongg"—Full Automatic System

80 are satisfied, 13 among these still have criticisms of a slight nature to bring forward. The subscribers readily avail themselves of the opportunity offered to present minor observations, etc.
12 are satisfied after the telephone service has been in operation a short time. Observations, none.
8 are dissatisfied altogether; all have criticisms to make.

Consultation of 100 Subscribers of the Sub-exchange "Oerlikon"—Full Automatic System

60 are satisfied; observations, none.
25 have been satisfied for some time.
15 are dissatisfied; all have criticisms to make.

Consultation of 100 subscribers of the Sub-exchange "Tiefenbrunnen"—Full Automatic System

71 are satisfied. Among these 12 have criticisms of a minor nature to bring forward.
21 have been satisfied for some time; one of them presented an observation.
8 are dissatisfied; all have criticisms to make.

Consultation of 100 subscribers of the Sub-exchange "Hottingen"—Full Automatic System

86 are satisfied. Among these 12 have criticisms of a minor nature to bring forward.
12 have been satisfied for some time. Among these 3 presented observations.
2 are dissatisfied; all have criticisms to make.

Remark: The cases of criticisms were dealt with later in writing.

Another means likely to correct wrong opinions is to invite the subscribers to visit the exchanges, so that they may place absolute trust in the installations. Thus, the Hottingen exchange, in the course of ten years, has been visited by about 4,000 persons, mostly in societies. The explanations given on those occasions by qualified employees have brought good results.

Finally, there is a certain class of scattered subscribers, to whom the exchange personnel must pay special attention. These persons are refractory and on account of their complaints and their unreasonable pretentions often cause the technical staff to lose their patience. At times, the cause of complaint is the message registering; they doubt the accuracy of the recording of the automatic message registers. It is true that errors in message registering are not altogether excluded, but as the number is small and often in favour of the subscriber, the

Swiss offices have every reason to acknowledge general accuracy. By special statistics, the proportion of errors has been established. Table III gives the results obtained in the Geneva Rotary exchange "Mont Blanc" during the months of January to May, 1926.

be obtained. The observations should be of such accuracy that the complainers are completely disarmed.

In order to have a record reflecting faithfully the traffic passing over the observed subscribers' lines, a relatively large amount of work is being

TABLE III

Message Registering Errors—"Mont-Blanc" Rotary Exchange

1926	Number of tests	Calls to exchange service; the message register should not operate	Calls to subscriber of:		Errors	
			"Mont-Blanc" the register should operate	"Stand" the register should operate	Total	%
January	2,961	..	1	6	7	0.24
February	2,990	2	..	5	7	0.23
March	3,002	3	..	1	4	0.13
April	3,223	..	1	4	5	0.15
May	2,964	..	1	8	9	0.30
Total	15,140	5	3	24	32	0.21

Table III shows that, according to exact reports, the percentage of registering errors for Mont Blanc has only been 0.21 per cent. It should be noticed that, as a rule, the subscribers readily pay the monthly taxes of the calls made through the Swiss offices. In certain cases where, for any reason whatever, the monthly indications of the registers were not exact (the message registers recording mostly too few calls and rarely too many) it has been easy to avoid losses, even for the Administration, after an understanding with the subscribers.

Nevertheless, in certain rare cases, it happens that subscribers continue making complaints, notwithstanding the fact that their complete installation, including the message register, has been tested with the utmost care and found perfect in operation. Such subscribers generally make a habit of recording their calls.

In this instance and also in the case where subscribers persistently complain of bad telephone service in general, the Administration have connected the subscribers' line to observation positions without informing them of this action. Although the organisation of the service observations fulfills the right purpose, nevertheless, these observations must be made with the utmost care in order that when it comes to definite discussion with the subscribers on the basis of irrefutable proof, the desired effect can

done. The effort is likely to be doubly profitable, first, because the controlled subscribers will hesitate in future to renew their criticisms and, secondly, because the public is thus informed of the effective means of control the Administration possesses. Fortunately, unwarranted cases of complaint are not numerous; the exchange Mont Blanc regained its calmness after a dozen of such observations. In cases of this kind, it is not only necessary to make the usual observation of the different phases of a call, but it is desirable to record exactly the hour when the call is established. Likewise, particulars of the conversation must be noted, such as the presumed name of the correspondent, etc.

On the basis of the results obtained through the observations made—of which the number is generally 100—a trustworthy official deliberates with the controlled complainers. This kind of deliberation provides surprises of different kinds.

Example I—The subscriber contends that his monthly account comprises 10 to 15 local calls too many.

Result—The service observations made involve a total of 50 conversations; the number of paying conversations correspond to the indications of the registers.

The subscriber himself had only recorded 46 during the same period, but after having examined the documents presented, he testified to having forgotten 4.

Example II—The subscriber complains that too many calls have been recorded on the account and that he has been wrongly connected several times.

Result—The office observes 115 calls which are distributed as follows:

Calls when the line was busy	4
Unanswered calls	2
Connections established, one of which wrongly	35
Calls to special services	7
Incoming calls	67
	115

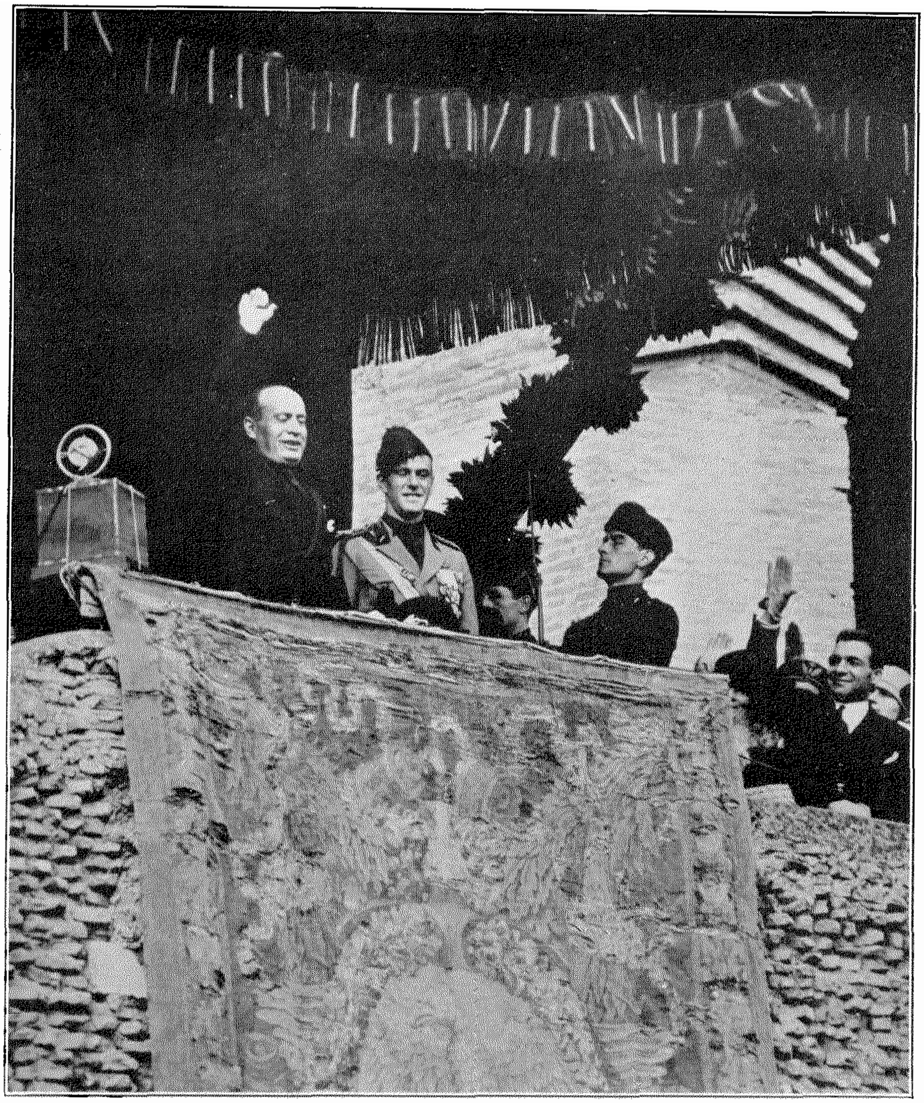
The message register had operated altogether correctly. The single false connection might have been due either to the switch mechanism or to the subscriber.

Example III — The subscriber complains strongly that he has been taxed too much, wrongly connected, etc.

Result—The office observes 273 calls of which the details are as follows:

The subscriber takes off the receiver and hangs up without having dialed the number	7
Same case, save that the subscriber dialed the number, but not completely	9
Calls when the line was busy	12
Unanswered calls	16
Connections established of which 4 wrongly	167
Calls to special services	62
	273

The indications of the message register were exact. The four false connections might be attributed either to the switch mechanism or to the careless work of the subscriber. The observations made enabled the office, nevertheless, to establish irrefutably that the calls of the subscriber were correctly handled and that his own mistakes had caused inconvenience both to himself and to the Administration.



Signor Mussolini Making a Speech at the Coliseum in Rome on the Occasion of the Fourth Anniversary of the Fascisti March on Rome. The microphone and amplifier employed in connection with the broadcasting of the program are shown at the left. They were furnished by Standard Elettrica Italiana

The Kone Loud Speaker

By S. HILL

Engineering Department, Standard Telephones and Cables, Ltd.

THE faithful reproduction of broadcast speech and music is a problem which requires for its solution painstaking study of the complete broadcasting system from the microphone in the carefully arranged studio to the loud speaker and its environment. The real measure of success can only be ascertained by direct comparison of the sounds originating before the microphone with those reproduced by the receiver. If these two performances are not noticeably different, then the problem can be said to have been satisfactorily solved.

A fundamental requirement in loud speaker design is that alternating currents corresponding to the frequencies encountered in musical sounds must be reproduced with uniform efficiency. In modern musical instruments, the frequency may vary from 30 to 10,000 cycles a second. Speech frequencies fall well within these limits.

Loud speaking receivers may be considered as consisting of two parts: a suitable mechanism, generally an electromagnetic device, for converting electrical impulses into mechanical movements, and a coupling device, whereby the motion of the mechanism is transferred to the surrounding air.

The mechanism used in the Kone loud speaking receivers is of the balanced armature type in which the armature with its attached diaphragm is not subjected to a magnetic pull unless a current is flowing through the coils. This has the great advantage that asymmetrical distortion due to unequal reproduction either of positive or negative portions of the energizing current is avoided. The stalloy pole pieces (a.a.), illustrated in Figure 1, are polarised by a large permanent magnet (not shown). The efficiency of the magnet system is increased by supporting the armature (b) centrally by means of spring lugs and suspending it symmetrically in the air gap. The coils (c.c.) occupy the cavity in the pole pieces and surround but do not touch the armature.

When current of speech frequency is passed through the coils, alternating poles are formed on the armature which is thus set into rotary vibration by interaction with the permanent magnetic field. The vibration is communicated to the diaphragm by means of the connecting rod (d), lever (e) and push rod (f). The whole mechanism is mounted on a rigid spider, screwed to the main frame.

In general, there are two types of mechanical-acoustic coupling devices, the small diaphragm with a horn and the large diaphragm without a horn. The function of the horn is analogous to that of a transformer inasmuch as it is capable of coupling two unequal impedances in a manner

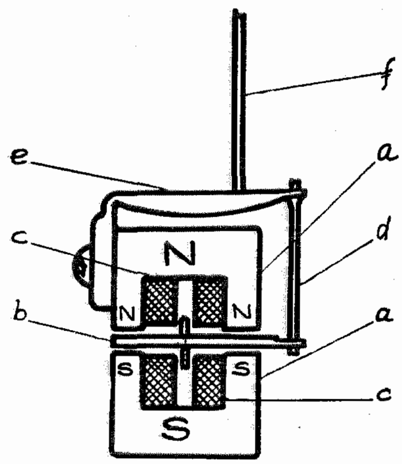
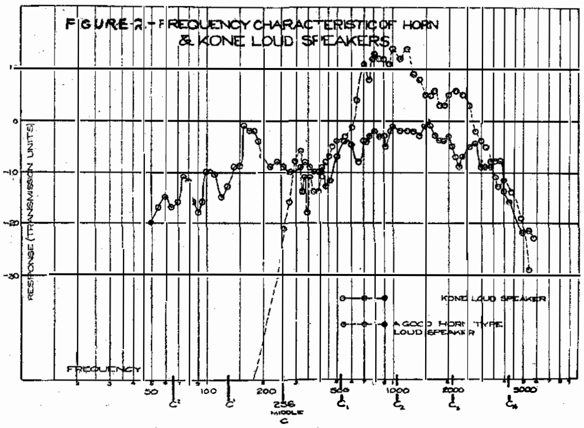


Figure 1—Balanced Armature Mechanism

such that the maximum possible energy transfer is secured. Owing to the limitations of physical materials, the small diaphragm is normally of high impedance in comparison with its radiation resistance in free air. It is, therefore, necessary to load it with the higher acoustic impedance represented by the narrow end of an exponential horn of slow taper. As a coupling device a horn is highly efficient, and modern methods of design enable it to be built so as to reproduce satisfactorily any desired frequency range. The theory of the horn, however, shows it to act as a high-pass filter; that is, there is for each horn a fairly definite cut-off frequency and below this frequency the horn ceases to operate satisfactorily. In order to provide for low frequencies, a low rate of taper and a considerable mouth opening are required so that horns capable of covering a satisfactory frequency range tend to become large and costly. The size fitted to the usual horn loud speaker is quite inadequate to handle the lower frequencies. In many cases, the quality of such receivers is harsh and unnatural due to poor reproduction of frequencies a little below middle "C" (250 cycles per second). It is for this reason that the large diaphragm type of receiver has been developed.



The large diaphragm type of coupling device introduces its own difficulties. Instead of a light sheet of air at the mouth of the horn, there is a material diaphragm possessing mass and elasticity. Owing to fall in radiation resistance, the efficiency at low frequencies decreases as the diameter of the diaphragm is made smaller.

The Kone type of loud speaker produced by Standard Telephones and Cables, Ltd., is an outstanding example of the large diaphragm instrument. The diaphragm consists of paper cones cemented around the bases which are approximately 18 inches in diameter. The apex of the cone is made to hold the push rod (f) of the magnet system (Figure 1). The rear cone is cut to a frustrum, the smaller circular portion being clamped to the frame. The back is closed in by means of a dust-proof screen. The frame, which is of suitably finished metal, is provided with a handle at the upper end. The appearance of the speaker is illustrated in Figure 6.

The material, shape and dimensions of the one diaphragm have been chosen to secure a compromise between weight and rigidity, the problem being somewhat complicated by the need for a material capable of meeting all ordinary atmospheric conditions. The paper used is particularly good in this respect; it is a hand-made bookbinding paper of close and uniform texture.

The constants of the diaphragm have been matched by trial in such a manner that the various modes of vibration of which the diaphragm is capable, blend to give a substantially uniform response over a wide range of frequencies, as indicated by the characteristic curve (Figure 2). These modes of vibration can be observed in the well-known manner by placing the diaphragm of the receiver in a horizontal position and sprinkling it with sand while a steady alternating electromotive force is supplied to the instrument from a suitable oscillator. It is found, in the case of the instrument discussed, that there are four distinct types of vibration: viz., (1) a rocking vibration about a diameter, (2) a sector vibration, (3) an annular vibration and (4) a transition between the last two forms. The first type of vibration (Figure 3) occurs at frequencies up to 100 cycles per second. Towards the lower end of this range there may be a fifth type of vibration in which the diaphragm moves as a whole. In the second mode of vibration, illustrated by Figures 4 and 5, the surface of the Kone moves in sectors varying in

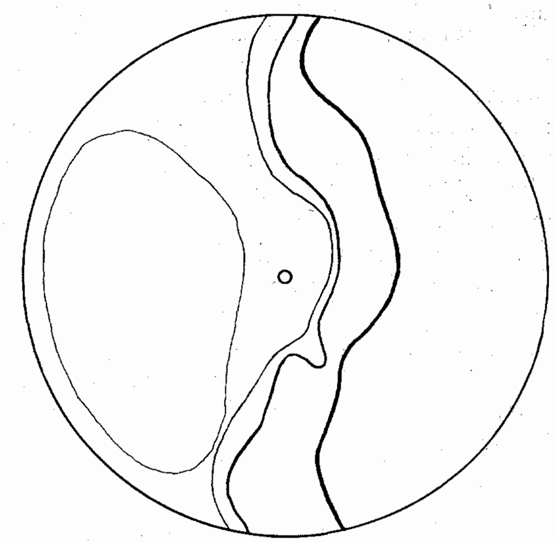


Figure 3—Sand Figure Obtained When the Kone Rocks about a Diameter

number from about 4 at 110 cycles per second, to 16 in the neighborhood of 150 cycles per second. Above about 800 cycles the Kone vibrates annularly, the sand being thrown into concentric rings. Between 150 and 800 cycles per second the transition stage occurs in which

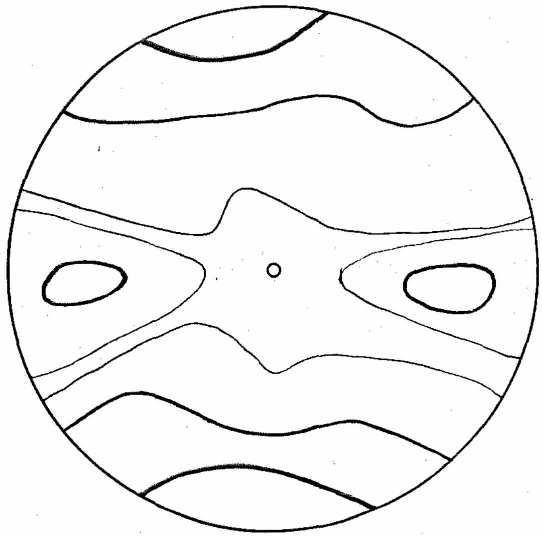


Figure 4—Sand Figure Given by Sector Vibration of the Kone at a Frequency of about 110 Cycles per Second

the sectors break up into small patches, arranged concentrically and decreasing in size as the frequency is increased. The blending of these various modes of vibration produces a large number of small resonances as shown in the response curve (Figure 2). These resonances, being both small and numerous, give results substantially the same as would be obtained from a smooth curve.

In order that the advantages indicated by the wide scope of the response curve may be fully obtained, the Kone must be operated under the proper conditions. This is especially important, since, as is well known, a loud speaker reproducing over a wide frequency range is more sensitive to overloading in its associated amplifier than is a loud speaker reproducing within a narrower range. It is evident also that unless the amplifier is capable of reproducing over a range at least as wide as that of the loud speaker, the advantages of the wider frequency range of the loud speaker may be completely lost. It frequently happens, for example, that the Kone is used with an inferior receiving set or amplifier which either distorts or does not reproduce some important part of the frequency range. In such cases the Kone cannot be expected to replace the missing frequencies or to correct the distortion. When used with a faulty set, the Kone may indeed sound worse than a greatly inferior instrument, because it can bring out defects in the set, such as distortion due to absence of grid bias or to overloading of the valves, which a poorer speaker might largely mask. There is no difficulty, however, in constructing a set, in accordance with known principles, capable of giving the high-grade performance necessary for obtaining the superior quality of reproduction which characterises the Kone Loud Speaker.

For home use a good receiving set and an amplifier terminating in valves of adequate power capacity as well as proper matching of the output of the loud speaking amplifier to the impedance of the Kone are well worth while.

If an amplifier be provided with an output transformer of variable ratio, so that its output impedance can be varied, and if a steady tone be

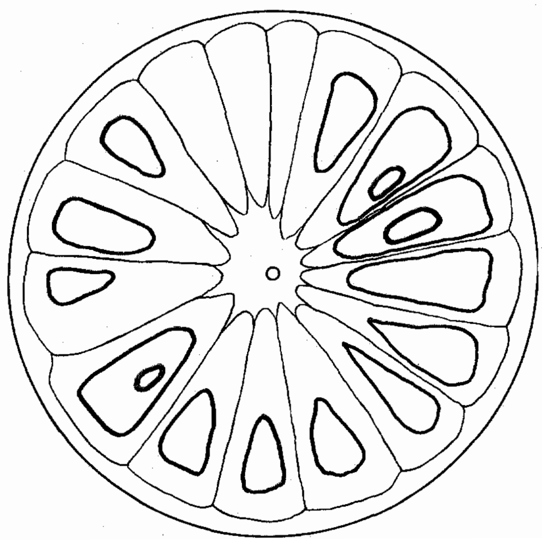


Figure 5—Sand Figure Given by Sector Vibration of the Kone at a Frequency of about 150 Cycles per Second

applied to such an amplifier and reproduced by a loud speaker, it will be found that maximum volume is obtained when the impedance of the amplifier is equal to that of the loud speaker. If the experiment be performed at different frequencies, the same setting probably will not give loudest results in all cases, because the impedance of the loud speaker at each frequency is not necessarily the same. Hence, a setting that gives exact impedance matching for one frequency does not necessarily do so for another. Under actual working conditions where the impedances are not capable of adjustment, there will always be one frequency which is reproduced better than the others because the impedance of the set and loud speaker match at this frequency. The choice of the impedance of the set or amplifier is important, because it con-

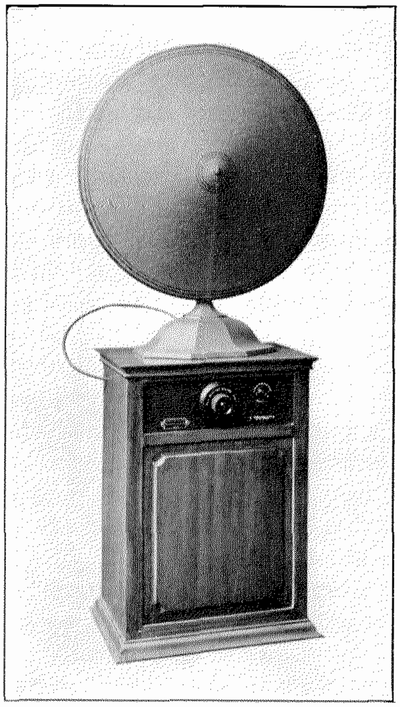


Figure 6—Kone Loud Speaker with Associated Kone Amplifier

trols the matching frequency and so influences the character of the performance. If the impedance of the amplifier is too high, matching will occur at high frequencies and may result in overaccentuation of the higher range. Similarly, if the impedance is too low, the lower frequencies are accentuated.

The design of the Kone produced by Standard Telephones and Cables, Ltd., is such that the best results are obtained from an amplifier of about 2,000 ohms impedance which gives impedance matching at about 300 cycles per second. The Kone, however, may be connected directly in the plate circuit of any good power valve without excessive unbalance of the tone scale, provided that the valve impedance does not exceed 10,000 ohms. Where it is used with valves of lower power handling capacity (which are gen-

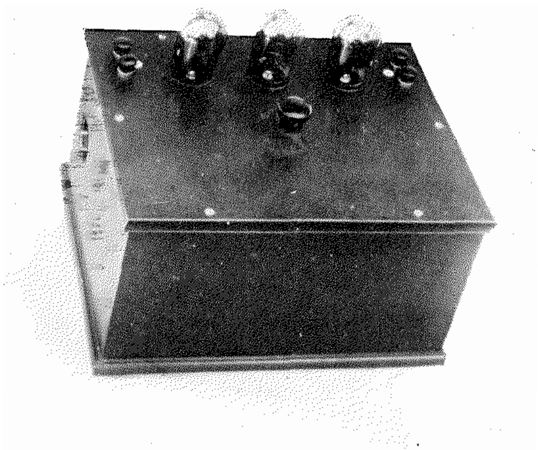


Figure 7—Amplifier Operating from D.C. Mains

erally of high impedance), a suitable transformer should be used to reduce the output impedance of the amplifier to 2,000 ohms.

An amplifier known as the Kone Amplifier has been specially designed by Standard Telephones and Cables, Ltd., for use with the Kone speaker (Figure 6). In addition to the valves, it contains two transformer coupled stages, and also an output transformer which gives the correct output impedance of 2,000 ohms. The three

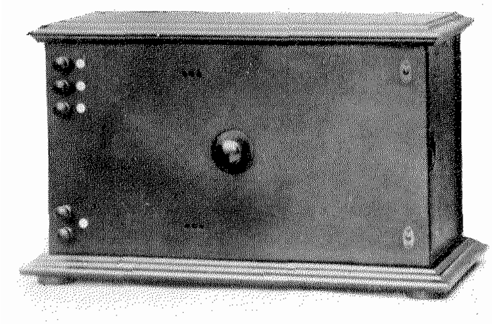


Figure 8—Amplifier Operating from A.C. Mains

transformers have been especially matched to produce substantially uniform amplification of all frequencies within the musical range.

As made by the Bell Telephone Manufacturing Company, Antwerp, the impedance of the

Kone Loud Speaker is twice that of the above mentioned loud speaker, and the corresponding amplifier impedance is doubled; hence, the preceding general remarks apply in terms of twice the impedances concerned.

A special associated two-stage amplifier is made by the Bell Telephone Manufacturing Company, which contains two valves in push-pull in the last stage, each of the same power

Figure 9—Large Kone Loud Speaker

handling capacity as those used in the previously mentioned amplifier. The amplification of this special apparatus corresponds to just over 50 transmission units, or to 10^5 on a power basis; its response characteristic for practical purposes may be considered flat between 50 and 5,000 periods per second. This amplifier is made in three forms which differ only in the nature of the power supply arrangements. One type is designed to operate from batteries, a second type is designed to operate completely from 110 volt D.C. mains, while a third type employing valves for rectifying purposes is designed to operate entirely from A.C. mains, taps being provided to adapt it to voltages of 110, 125, 150 and 220. Filters are provided to eliminate noise from the power mains. The second and third types are shown in Figures 7 and 8, respectively.

The conditions under which a loud speaker is heard have an important bearing on the quality of reproduction. If, for instance, a person is speaking in a quiet conversational tone and the volume delivered by the loud speaker is made too great, the result will sound unnatural; whereas, if he is speaking as if addressing a considerable audience, natural reproduction can best be secured by increasing the volume and listening as far away from the receiver as possible. Reverberation, or reflection in the room, also plays an important part in reproduction. If possible, therefore, experiments should be made to determine the most suitable position for the loud speaker.

It is evident that no loud speaker should be expected to remedy the shortcomings of the receiving apparatus and amplifiers which precede it; and, in order that the best results may be obtained from the Kone Loud Speaker, it is necessary that ordinary precautions be observed in the design of such apparatus. With a simple resistance coupled amplifier terminating in almost any well-known make of power valve, the Kone Loud Speaker is capable of reproducing the rich tones of an organ or a pianoforte accompaniment with surprising fidelity. Sibilant speech sounds are also well reproduced.

In addition to the 18 inch speaker, a Kone type (Figure 9) employing a diaphragm 36 inches in diameter and the same magnet system as the smaller instrument has been developed. It is intended for use with a radio receiving set but under certain conditions can be employed with a Public Address System. It reproduces the lower notes of the cello, organ and piano and the brass instruments even more faithfully than the 18 inch Kone.

European Telephony as Affected by the International Telephone Committee—"C. C. I."

AMONG the very interesting phenomena, which occurred in Europe in the years immediately following the War, was a crop of so-called "international" organisations. The scope of these numerous bodies covers a wide field of activity in commerce and industry, as represented by railways, tramways, electric traction of all kinds, sleeping cars, production and distribution of electricity, telephony, telegraphy, broadcasting, etc. To trace the causes of this movement towards internationalism (which, *faute de mieux,* means "Europeanism") would be an interesting study for psychological historians. There appears to be no doubt, however, that if not directly caused, it certainly received a powerful stimulus and impetus from the propagation of the idea underlying the creation of the League of Nations. In view of the importance which one of these organisations, known as the "Comité Consultatif International des Communications Téléphoniques à Grande Distance" (generally abbreviated to "C.C.I.") has assumed in the development of telephony in Europe, readers of this journal will doubtless be interested to have some information with regard to its composition, its aims and its achievements.

In order to obtain a clear idea as to what this body is and does, it is desirable to examine briefly its history. The movement towards internationalism in this particular case was undoubtedly strengthened by the striking advances in the field of long-distance telephony, which had taken place immediately before and during the War. The development and application of the 3-electrode vacuum tube in the telephone art gave the telephone engineer a tool which enabled him to accomplish astonishing achievements and to annihilate distance as an obstacle to telephone communication.

As an example of what was done, it is well known that all the main armies were using telephone repeaters on both underground and open wire lines. Immediately upon the conclusion of peace several European countries, notably Germany, Great Britain, Holland and Sweden commenced actively the installing of new long-distance cables in their respective territories. Other countries, for example, France, Italy and Switzerland, began the planning of national long-distance cable networks.

The main technical problems of long-distance telephony had already been practically solved; any reasonable doubt on this score had been effectively removed by the fact that, as early as 1915, commercial telephone service was given in the United States between Boston and San Francisco, a distance of 5,840 kilometers. What was needed in Europe after the War was some impetus to bring together the various telephone administrations and, in some way, so to co-ordinate their efforts in the utilization of existing telephone plant and in the design of new equipment as to make European long-distance telephone communication a commercial success.

In 1922 a new phase was commenced. Mr. Frank Gill, European Chief Engineer of the International Standard Electric Corporation in his Presidential Address to the Institution of Electrical Engineers (British) delivered on November 2, 1922, called attention to the urgent necessity of treating international telephony on a unified basis; and of three definite proposals then made, one was that the operating telephone authorities should form an association for this and other matters and that an early international conference should be held to initiate the project.

On March 12, 1923, an international meeting took place in Paris, at the invitation of the French Government, expressly to consider these proposals and the existing C.C.I. is the direct and immediate descendant of that meeting.

At this conference the following countries were represented: Belgium, France, Great Britain, Italy, Spain and Switzerland. The conference met in the form of a "Preliminary Telephone Committee for Long-Distance Telephony in Europe," and resolved, as a result of the deliberations, to form a permanent body, to be known as the "Comité Consultatif International des Communications Téléphoniques à Grande Distance" with the task of "preparing completely the organisation of international telephony in Europe." As a first step towards this end, the Committee resolved to attempt to unify the views and practices of the various telephone administrations of Europe and to centralise technical and statistical information.

It was clearly laid down that resolutions which might be taken by the C.C.I. would be in the nature of general recommendations, to which the various countries of Europe should be invited to conform as strictly as possible in their own as well as in the common interest. It was also decided that the Committee should meet generally once a year. A Permanent Sub-Commission was formed to maintain continuity between conferences. This Sub-Commission was composed, in the first instance, of a representative from each of the following countries: Belgium, France, Great Britain, Italy, Spain and Switzerland, each delegate having one vote in the deliberations.

The first conference of the C.C.I. proper, took place in April, 1924, and was convened as a result of the preliminary meeting in the previous year. At this conference, the following countries were represented: Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Holland, Hungary, Italy, Latvia, Luxembourg, Norway, Poland, Sweden, Switzerland, Czecho-Slovakia and Yugo-Slavia. Representatives of the telephone industry were also invited to collaborate and advise in the deliberations as assessors to their respective administrations, but with no voting power. The conference confirmed the resolution referred to above, passed by the preliminary conference, affirming the main object of the C.C.I. The following additional countries, it was decided, should be added to the Permanent Commission: Austria, Germany, Holland, Czecho-Slovakia and Yugo-Slavia. The task of the Permanent Commission was to prepare and facilitate the work of the C.C.I. and the practical and detailed application of the decisions taken by the Committee, and to indicate the methods of execution.

The administrations belonging to the C.C.I. were invited to communicate to the Permanent Commission all the proposals for new international lines, together with essential technical details. Where these proposals deviated in any way from the general recommendations formulated, the whole of the details of the proposals were to be submitted to the Permanent Commission in order that the latter might be able to study any modifications that might be made to existing rules.

The second conference of the C.C.I. was held in Paris in June, 1925, and the third and latest conference in the same place in November, 1926. The number of countries participating have now increased approximately to twenty-five, the additions being Lithuania, Portugal, together with her Colony, Mozambique, Rumania and the Union of Sovietic and Socialistic Republics (generally abbreviated "U.S.S.R.").

The admission of Mozambique and U.S.S.R. was due to an interesting development which took place between the second and third conferences of the C.C.I. The Communications and Transit Organisation of the League of Nations had had its interest aroused by the importance of the role which the C.C.I. was filling and was evidently destined to fulfill in the domain of European communications, and had suggested the affiliation of the C.C.I. with the League of Nations, in accordance with the terms of the Peace Treaty of Versailles, which provided that any organisations of an international character founded subsequent to the Treaty would automatically form part of the League of Nations. Unfortunately, Germany was not then a member of the League of Nations, and she naturally felt that the important position which, by virtue of her technical achievements and experience in long-distance telephony, she had acquired in the counsels of the C.C.I. would be undermined if that body were taken over by the League of Nations, in which she had no place. A way out of the difficulty appeared to be the incorporation of the C.C.I. in the International Telegraph Union, of which the first conference after the War took place in September, 1925. This solution found support in various countries in the centre, east and north of Europe, and was ultimately adopted by a resolution passed at the conference of the International Telegraph Union. By this resolution the C.C.I. was incorporated in the Union. The resolution forms the present charter of the C.C.I. It does not go quite so far as to assert that the C.C.I. "should be entrusted with the complete preparation of the organisation of telephony in Europe," but states merely that the C.C.I. shall be entrusted with the study of standard arrangements regulating technical and exploitation questions concerned with long-distance telephony. The C.C.I., it lays down, shall centralise all information which is necessary for the study of long-distance telephony, and pass resolutions on the subject. Otherwise the International Telegraph Union leaves the C.C.I. free to establish its own organisation and methods of work with the proviso that the Union be kept informed of all the resolutions passed, which, in future, have to be published in its official organ—the "Journal Télégraphique." Two facts of importance resulted from this action on the part of the Telegraph Union. The first was that the League of Nations can no longer claim the incorporation of the C.C.I. in the League organisation; secondly, any government administration of any country belonging to the Union, which embraces the whole world, as distinct from Europe only, can now become a member of the C.C.I. on application. By virtue of this latter fact it was that the Union of Sovietic and Socialistic Republics and Mozambique were admitted to membership of the C.C.I. at the third conference.

At the November, 1926, conference, the internal organisation of the C.C.I. was modified. The Permanent Commission was abolished. This Commission had been found to be somewhat unwieldy and had not in point of fact been able to carry out satisfactorily, owing to its size, the functions for which it was originally intended. The following is a resumé of the new organisation of the C.C.I.: In place of the Permanent Commission it was decided to constitute "Commissions de Rapporteurs." These Commissions have to be appointed by the full conference of the C.C.I., to be held once a year. Their number and constitution depends upon the number and nature of the questions to be studied. Each Commission appoints a Rapporteur Principal, responsible for directing the work of the Commission. The rapporteurs make a detailed study of the questions submitted to them for investigation, and each group endeavours to arrive at common agreement and to prepare, if possible, a unanimous report on their conclusions. If necessary, the rapporteurs meet at some agreed place and confer amongst themselves or with the collaboration of representatives of the private electrical industry. The agreed reports, together with the supporting documents, have to be forwarded to the General Secretary of the C.C.I. in Paris, at least a month before the date of the full conference, so that the reports may be circulated to delegates, who will be present at the full conference, and so that these delegates may have time to peruse and consider the reports before the conference meets. The reports are discussed at the full conference and voted on by delegates. The minutes show in each case whether the reports have been adopted unanimously or by majority only. The General Secretary, whose office is in Paris (23, Avenue de Messine) is elected for an indefinite period, but the President of the C.C.I. is elected annually at the full conference (Assemblée Plénière).

Let us now try to disengage from the foregoing somewhat sketchy summary of the history of the C.C.I., a clear idea of what this body is, and the purpose for which it has been constituted.

The C.C.I. is a branch of the International Telegraph Union. It is allowed to arrange its own internal organisation and has a separate budget, to which members appointed by twenty-five government administrations, comprising practically the whole of the countries of Europe, contribute on a basis fixed from time to time by itself. It holds a conference at a centre agreed upon, once a year. At these conferences are discussed the reports, affecting the development of telephony in Europe, which have previously been studied by selected delegates (known as "Rapporteurs") nominated by certain government administrations, who themselves have been elected for this purpose at the preceding conference.

The President of the C.C.I. is elected annually; he is assisted by a General Secretary and Secretariat with headquarters in Paris. The General Secretary centralises and distributes information obtained from all sources to the rapporteurs, whose "rapports" he receives and circulates before conferences to all members of the C.C.I. He also communicates with other international bodies in connection with any queries, requests for information, etc., which these bodies, as well as administrations, may address to the C.C.I. from time to time. The questions, studied and discussed by rapporteurs and by all members at annual conferences, relate to the investigation of the developments and improvements affecting telephony in both its technical and its operative aspects. When new inventions and methods suitable for international adoption come to light, the C.C.I. studies these in detail and endeavours to specify the best methods by which they can be applied, in a standardised form, in practice. The conclusions arrived at as the result of conferences, to which experts from the private industry, as well as representatives from other international bodies, such as the Advisory and Technical Commission of Communications and Transit of the League of Nations, the International Union of Railways, the International Chamber of Commerce, the International Electro-technical Commission, the International Union of Wireless Telephony, etc., may send delegates, if they desire, are embodied in the form of resolutions which are sent officially by the General Secretary to administrations which, although not strictly obliged to adopt them, must necessarily take cognisance of the moral force behind them.

The work of the C.C.I., for convenience, has been divided into four distinct parts, as represented at conferences by four sub-commissions, viz.:

(1) Sub-Commission on General Organisation (of which the President has hitherto been the President of the C.C.I.—at present Monsieur Milon, France)
(2) Sub-Commission on Telephone Transmission Plant (President, Colonel Purves, Great Britain)
(3) Sub-Commission on Protection of Telephone Lines from Interference by Power Lines (President, Dr. Breisig, Germany)
(4) Sub-Commission on Traffic and Exploitation (President, Mr. Van Embden, Holland)

It may be convenient to deal with the work accomplished by the C.C.I. in the order indicated by these four classes.

(1) The first, and one of the most important objects achieved has been the creation of a corporation representing all the principal countries of Europe, which, by means of periodical conferences, has put the representatives of European Administrations into close personal and friendly touch with one another. This has been found to be of the greatest value, not only in so far as the work of the C.C.I. itself is concerned, but also in regard to the day-to-day work of Administrations which, under the present intensive development of long-distance telephony, necessarily have constant relations with one another in the establishment of new international circuits and the drafting of international agreements. It has also provided a channel through which the private electrical industry and international organisations of all kinds, interested in electrical communications, may keep in touch with administrations and obtain information as to the common views of the latter in matters affecting the work of these firms and organisations.

The C.C.I. also provides a safeguard to smaller administrations, lacking in practical experience in long-distance telephony, in so far that by the adoption of the recommendations of the C.C.I., they are assured of having at their disposal the best and most modern technical advice in connection with the construction and maintenance of their telephone plant. In their dealings with contractors, they in this way obtain a large measure of independent control over tenders and proposals.

By means of the C.C.I. also, the private electrical communications industry is able to follow the views and tendencies of administrations and to know on what lines development of research and modifications of constructional plant, is likely to achieve the best results in their dealings with administrations throughout Europe.

(2) One of the earliest and most important tasks accomplished by the C.C.I. has been the drafting, in broad outline, of standard specifications concerned with all the main classes of long-distance telephone plant (cables, repeaters, loading coils, testing apparatus, etc.). In the compilation of these specifications, the object of which has been to ensure uniformity of practice throughout Europe, representatives of the private industry have invariably been consulted in order that stipulations might reasonably conform with possibilities of actual construction.

Regulations have been drawn up which have in view standard methods of maintaining and working long-distance lines (with their accessories) when these have been constructed and brought into use.

The unit of telephone transmission to be adopted by the various countries in Europe was decided provisionally at the November, 1926, Conference. A general agreement, regarding the nature and object of the transmission unit, had been reached in that it shall serve to express the ratios of apparent and real powers, voltages or currents, and that in practice the logarithms of these ratios shall be used. Since some administrations prefer to use the decimal (or Briggs) system and others the Naperian system of logarithms in expressing the unit of transmission, it was decided that, in international traffic, the unit may be expressed on the basis of either system, but no administration shall claim the exclusive use of the unit it adopts.

The controversy over the Transmission Unit, which is the one disappointing feature of the work of the C.C.I., has at any rate had the advantage of bringing the United States through the American Telephone and Telegraph Company into close relation with Europe. The American Telephone and Telegraph Company was so good as to send representatives to a meeting in November, 1925, at which the Transmission Unit controversy was one of the main topics of discussion.

Another matter of first-class importance is the decision by the C.C.I. to establish in Paris a so-called Master Standard Reference System to be used and maintained in Paris for the purpose of enabling the countries of Europe to standardise their telephone apparatus in accordance with a common, agreed datum. This Standard Reference System will be identical with that used in America. Its composition formed the topic of discussion at a special conference of a sub-commission of the C.C.I. in London in May, 1926, where it was finally decided to adopt the system which would be used in America. Through the generosity of the American Telephone and Telegraph Company, the European Master Standard Reference System is being constructed and supplied as a free gift to the C.C.I. by that Company and it is expected that this system will be installed in Paris this Autumn.

Amongst the numerous other questions dealt with and on which decisions have been taken, may be mentioned the construction of a special type of underground cable for the purpose of interconnecting broadcasting centres in Europe. The possibilities of carrier current telephony, and the co-existence in the same cables of telegraph and telephone circuits are also under discussion and will be dealt with at the next conference of the C.C.I. to be held next September in Como which is to be the scene of numerous technical conferences on the occasion of the Centenary of the death of Volta. At this conference will also be discussed the question of unifying systems of loading telephone cables, with a view if possible to arriving at such a uniform system as will provide for future very long circuits without the necessity of making subsequent changes when circuits are extended.

(3) A very important part of the work accomplished by the C.C.I. has been the formulation of what has been termed "Directives" (guiding principles) to be adopted with a view to protecting telephone lines from interference by adjacent high power plant. In this connection it has been necessary to discuss matters in common with the electric power industry and the International Union of Railways. There are several points still in dispute in this connection, owing to the fact that the railways and the producers and distributors of electric power current consider the restrictions which it is proposed to impose on them by administrations are too severe. To get over this difficulty, it has been arranged to carry out a programme of tests to be conducted in various countries jointly by administrations and the electric power industry, in order that it may be verified whether or not the limits proposed by the C.C.I. are reasonable. The discussions on this question of protection have involved a great deal of elaborate and highly scientific work, the results of which as incorporated in the publications of the C.C.I. will be of great general interest. With this work has been associated investigations of the questions of the protection of telephone lines from corrosion due to electrolysis and chemical action.

(4) In addition to the engineering questions referred to above, which form the subject of discussion and decision by the C.C.I., advantage has been taken of the presence of representatives of most European countries at the con-

ferences of the C.C.I. to discuss questions relating to traffic and the best means of working long-distance circuits from that point of view. In telephone enterprises, like other commercial undertakings, the question of the charges to be made to the public is of course vital, but the actual rates to be charged for calls on long-distance lines in Europe have to be settled by direct agreement as the result of bargaining between the administrations concerned. Certain principles, however, have been settled as a result of discussions at the C.C.I. conferences on a number of points, such as the following: minimum traffic to be assured to transit countries in the establishment of new lines; determination of the number of calls to be allowed on any given circuit; the degree to which tariffs varying according to the hours of the day should be adopted; the number of circuits to be served by one operator; the decentralisation of traffic by the creation of zone centres; the preparation, say by telegraph, of calls; the sub-division of three minute units; and the admission of subscription calls.

The C.C.I. has also been used in this connection for the purpose of compiling statistics relating to actual costs in the construction of plant (as a basis for fixing charges) and of statistics for the purpose of estimating future traffic. The C.C.I. as a dependent of the International Telegraph Union also discusses questions arising out of the regulations with regard to telephone tariffs and traffic arising out of the "Service Regulations" laid down by the conference of the International Telegraph Union. The personal touch established between representatives of the Traffic Departments of the various administrations has been of particular value.

In addition to the above brief summary of what the C.C.I. has done and is doing may be mentioned the useful, miscellaneous functions which it has fulfilled in the way of centralising information of all kinds relating to long-distance telephony. Articles appearing in various languages in the technical press are translated into French (the official language of the Committee) and circulated. A vocabulary of telephone technical terms is being prepared.

The difficulties of working the telephone system of Europe as a whole are considerable, particularly in regard to the vital question of establishing some kind of unity of control. Europe is divided into a large number of more or less water-tight compartments, representing countries in various stages of development, possessing different ideas, different languages and different methods of work. The administrations which have to work telephone systems within the various political boundaries are responsible to their several parliaments and the ministers concerned are liable to change with their governments. In these circumstances, it is very difficult to induce the heads, for the time being, of the different States to undertake anything in the nature of risks normally taken by every commercial undertaking in connection with the outlay on expensive plant, from which the revenue is essentially problematic. When these difficulties are borne in mind and the post-war political conditions in Europe are kept in view, it will probably be admitted that the C.C.I. has fulfilled and is fulfilling a very useful function.

Paris-Strasbourg Cable

European Engineering Department, International Standard Electric Corporation

Introduction

An outstanding event from the viewpoint of European international long distance telephony was the completion in September, 1926, of the Paris-Strasbourg toll cable provided by the French Government. The cable is 494 kilometers in length and traverses several important industrial areas, such as Champagne, Lorraine and Alsace—the first famous for its wines, the second for its heavy industries and the last for its agricultural produce. In addition to providing communication between Paris and the districts mentioned, international telephone traffic is dealt with by connections from Paris to: England and Belgium; northern and central Germany, by way of Nancy and Strasbourg; and Switzerland and Italy, through Selestat. Some of the circuits involved are installed in underground cables, while others which at present are in the form of open wire lines probably will be placed underground in the near future. The maps of France and Europe (Figures 1 and 2) show the cable route and give some indication of the importance of the new system in the European communication network.

At the end of 1923, the contract for the supply and installation of a loaded and repeatered underground telephone cable was placed with Société Anonyme, Lignes Télégraphiques et Téléphoniques, concessionaires in France of the International Standard Electric Corporation for the manufacture of long distance telephone cables and the installation of complete toll cable systems. That concern manufactured and installed all the cable and also installed the loading equipment which was manufactured by Le Matériel Téléphonique, the French Associated Company

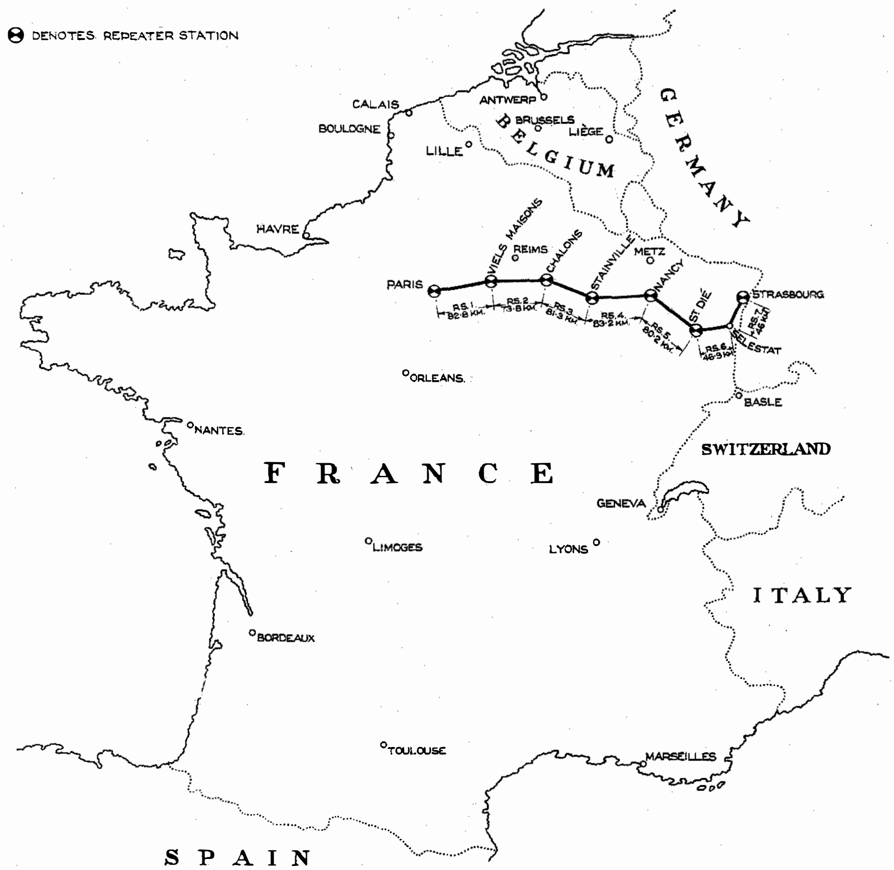


Figure 1—Map of France Showing Paris-Strasbourg Cable Route

of the International Standard Electric Corporation.

Immediately after the closing of the contract, the work of manufacturing the cable and accessories was started, and schools were established for the training of the personnel required. These schools were maintained for over two months, and the first lengths of cable were laid in May, 1924. The cable laying was completed by the end of 1925 and jointing and testing as well as installation of the loading coils followed so closely that by the end of January, 1926, all work on the system was finished with the exception of the repeater installation. By April, 1926, fifty circuits were brought into operation, and by September of that year the whole system had been handed over to the French Administration.

General Description

The system which it is proposed to describe in this paper is a loaded cable between Paris and Strasbourg, provided with seven repeater stations. Figure 1 indicates the route followed by the cable and shows the spacing of the repeater stations. The route was chosen after a detailed study of the possible sources of interference in the districts to be traversed and, as finally selected, gives the desired degree of separation between the cable and electric power lines or railways. To reduce to a minimum the danger of wilful or accidental damage, it was decided to lay the cable underground throughout the route. In the open country, the cable is protected by an armouring of steel tape and laid direct in the ground, the average depth of the trench being sixty centimetres, but when crossing villages or other exposed localities the depth was increased to eighty centimetres, and in addition a warning strip of wire netting was placed twenty centimetres above the cable. Where the depth was insufficient to afford natural protection, the cable was placed in Zores iron troughing which, in localities of exceptional shallowness, was encased in concrete. When traversing main roads and level crossings, the cable was pulled into iron

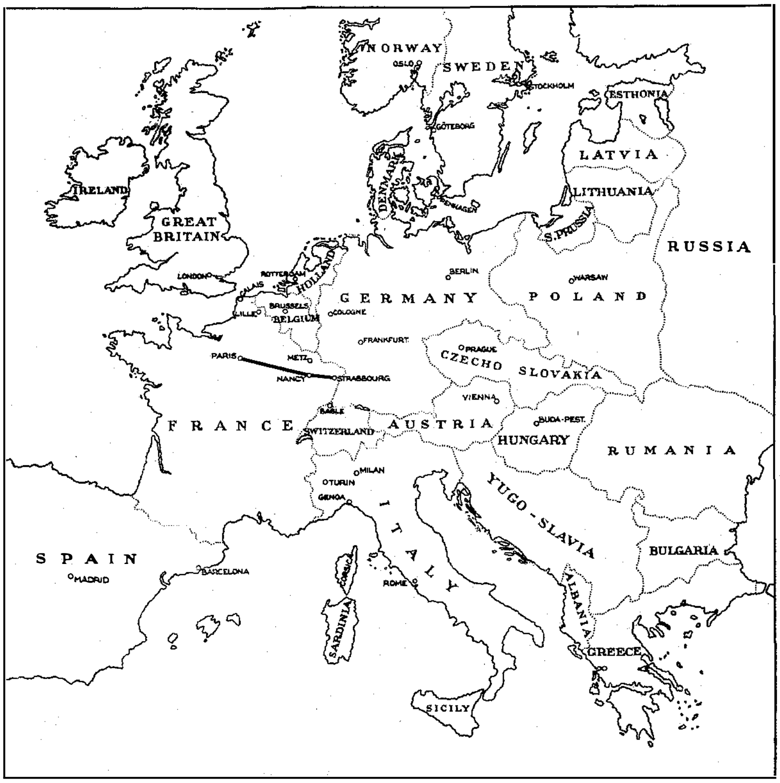


Figure 2—Map of Europe Showing Route of Paris-Strasbourg Cable

piping. In the larger towns plain lead covered cable pulled into ducts of concrete block construction was used, and in Paris the cable was placed in a special cable subway.

On the main route between Paris and Strasbourg, two sizes of cable, having both telephone and telegraph quads, are employed. The telegraph quads are in the centre of the cable and screened from the telephone quads by means of a layer of aluminum tape. From Paris to

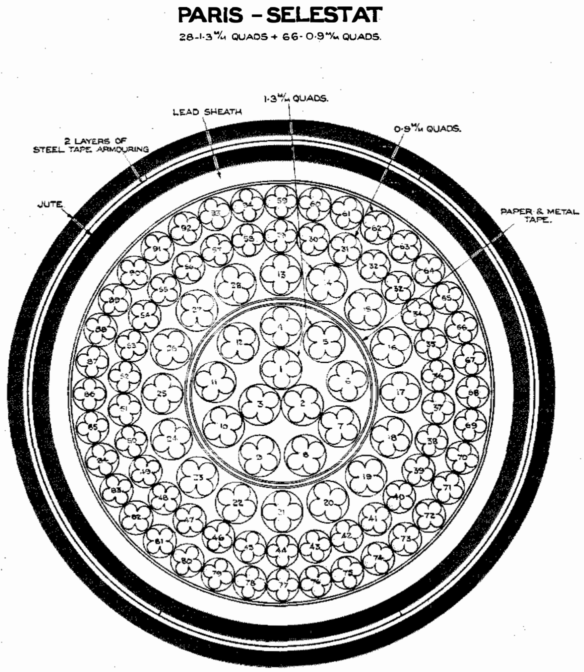


Figure 3—Cross Section of the Paris-Selestat Cable

Selestat, a distance of 450 kilometres, the cable consists of

66 quads of 0.9 mm. conductors } for telephone working
16 quads of 1.3 mm. conductors }
12 quads of 1.3 mm. conductors—for telegraph working

and, from Selestat to Strasbourg, a distance of 44 kilometres, of

42 quads of 0.9 mm. conductors } for telephone working
22 quads of 1.3 mm. conductors }
7 quads of 1.3 mm. conductors—for telegraph working

The cross sections of these cables are shown in Figures 3 and 4.

Although blasting with dynamite was found necessary at a few points where the ground to be traversed was very rocky, the excavation of the trenches was performed almost entirely by hand. Figure 5 shows a machine employed for placing the cable in the trench.

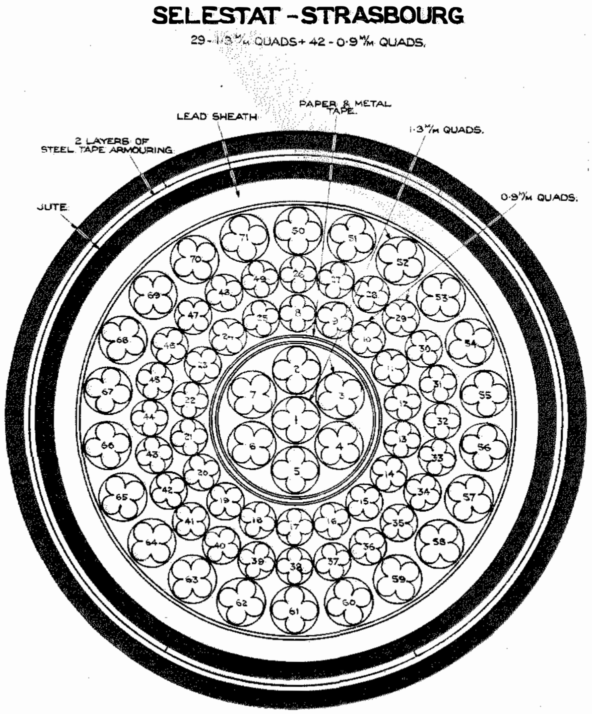


Figure 4—Cross Section of the Selestat-Strasbourg Cable

Tests were made during installation in order to reduce unbalances by the cross-splicing method to values sufficiently low to ensure satisfactory overall results. These tests included capacity unbalances, unbalances to earth, and capacity deviation; in addition, tests such as loop resistance, resistance unbalance and insulation resistance were made as a check on the installation work.

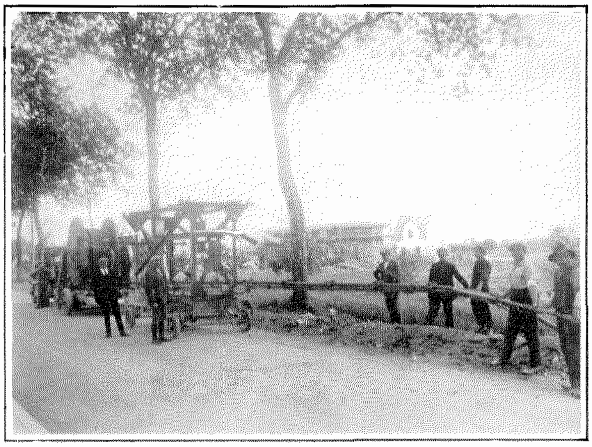


Figure 5—Cable Placing Machine

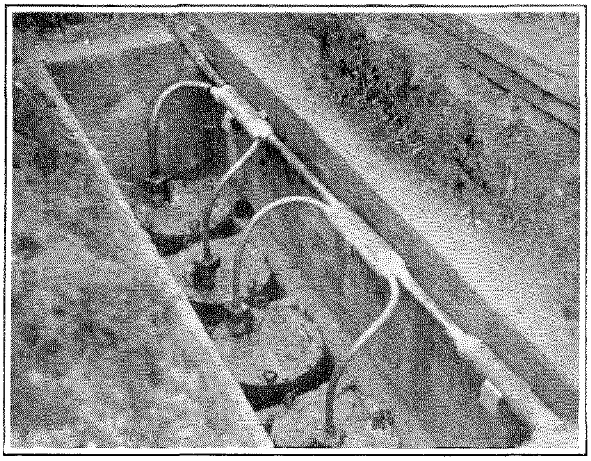


Figure 6—Loading Coil Cases Installed in a Manhole

Two types of loading are provided: viz., H-177-107 and H-44-25, the letter H signifying a spacing of about 1.8 kilometres, the first figure the inductance in millihenries of the side circuit coils, and the second figure that of the phantom circuit coil. The type of loading coil case is illustrated partially in Figure 6, from which it will be seen that a single stub is fitted to each case, thus enabling the coils to be connected to the cable without undue congestion of joints. This is particularly important where the number of cases to be installed is large.

Figure 7 shows a loading coil case being lowered—from a special type of motor lorry conveyor—into the manhole (Figure 6), which is of simple and economical design. In addition to accommodating the four loading coil cases required to load the telephone quads, the manhole provides space for the fifth case which will be required if it should be decided to load the telegraph quads.

Joints in the armoured cable other than at loading points are protected by means of split couplings of cast iron buried directly in the earth. Concrete jointing chambers are used for joints made in unarmoured cable when passing through towns.

The cable is designed to provide three types of circuits:

(a) 2-wire loaded H-177-107 for the shorter national circuits.

(b) 4-wire loaded H-177-107 for long distance national traffic.

(c) 4-wire loaded H-44-25 for international traffic.

The total number of circuits at present in operation is about 200, among which there are many important long distance circuits.

Repeater Equipment

There is a total of seven repeater stations on the Paris-Strasbourg cable route, the principal items of repeater equipment at each station being as follows:

	4-Wire Repeaters		2-Wire Repeaters		Voice Frequency Ringers		4-Wire Terminating Sets	
	Initial	Ultimate	Initial	Ultimate	Initial	Ultimate	Initial	Ultimate
Paris	75	84	..	..	94	140	69	103
Viels-Maisons	31	79	36	51	..	..	..	..
Chalons	75	84	..	..	5	7	..	..
Stainville	31	79	36	51	..	..	3	3
Nancy	75	89	1	7	22	24	8	8
St. Die	30	63	37	46	4	9	4	20
Strasbourg	26	26	5	5	31	32	25	26
Totals	343	504	115	160	156	212	109	160

At Paris, Nancy and Strasbourg, the existing telephone buildings are used for the repeater equipment, while at the remaining stations special buildings were constructed which not only provide accommodation for the repeater equipment and power plant but in most cases living quarters for the maintenance staff.

The layout of the equipment of the repeater

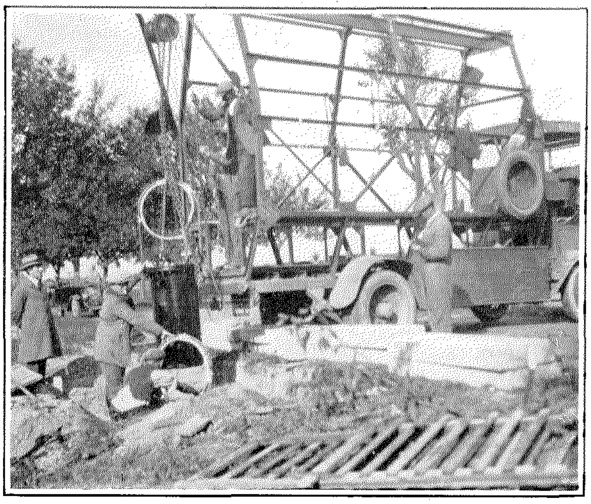


Figure 7—Motor Lorry for Transporting and Lowering Loading Coil Cases into Position

stations was completed in 1924 and embodied the best then known practice, the underlying aim having been to provide the maximum possible flexibility in the arrangement of the apparatus so that any circuit or combination of apparatus might be quickly set up or modified. With this end in view, the apparatus was assembled in groups of the same type, each group having been terminated at the distributing frame for connection by means of "jumper" wires into the required circuit combinations. Emergencies and unforeseen traffic demands can thus easily be met by simple changes in the jumper wiring.

An article by Mr. A. B. Hart, dealing with the London-Glasgow Trunk Cable,[1] describes repeater station equipment which is very similar to that installed on the Paris-Strasbourg cable and it, therefore, seems unnecessary to enter into a detailed description of this equipment in the present instance. It may be of interest, however, to touch upon certain points of difference, and, in particular, the method of connecting the main cable circuits to the repeaters.

The main cable is terminated at each repeater station by splicing it at a convenient point inside the station to two or more silk and cotton insulated lead covered cables which, in turn, are connected to protectors on the combined distributing frame. From the protectors the cable circuits are cross-connected by means of jumper wire to terminal blocks on the vertical side of the frame; they then are run through lead covered cable to the toll test board (Figure 9) and thence to the repeater equipment through jacks.

The toll test board, which is provided with testing equipment consisting of voltmeter and Wheatstone bridge testing circuits, as well as facilities for talking and ringing on the cable circuits, is so designed that routine tests can be made quickly on any cable circuit. It also provides a rapid means for bringing into service, when necessary, spare circuits or equipment.

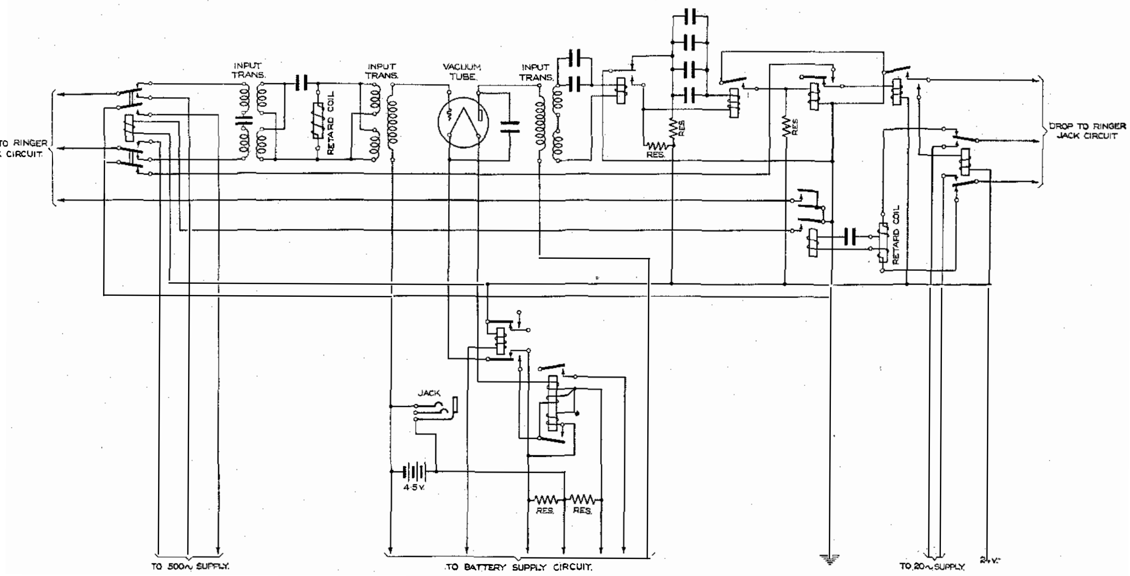


Figure 8—Voice Frequency Ringer—Circuit Schematic

While the ringing supply in the Paris-Strasbourg cable is similar to that described in the case of the London-Glasgow cable, there is a difference in the ringer panels. Figure 8 is a circuit schematic of the panel employed in the Paris-Strasbourg cable. The circuit consists of the following parts:

1. An input circuit tuned to 500 cycles.
2. A vacuum tube rectifier.
3. A 20-cycle tuned circuit operating from the output of the vacuum tube.
4. A train of direct current relays.

The train of direct current relays has a time delay element and this feature, combined with

[1] "The London-Glasgow Trunk Telephone Cable and Its Repeater Stations," A. B. Hart, ELECTRICAL COMMUNICATION, Vol. 5, October, 1926.

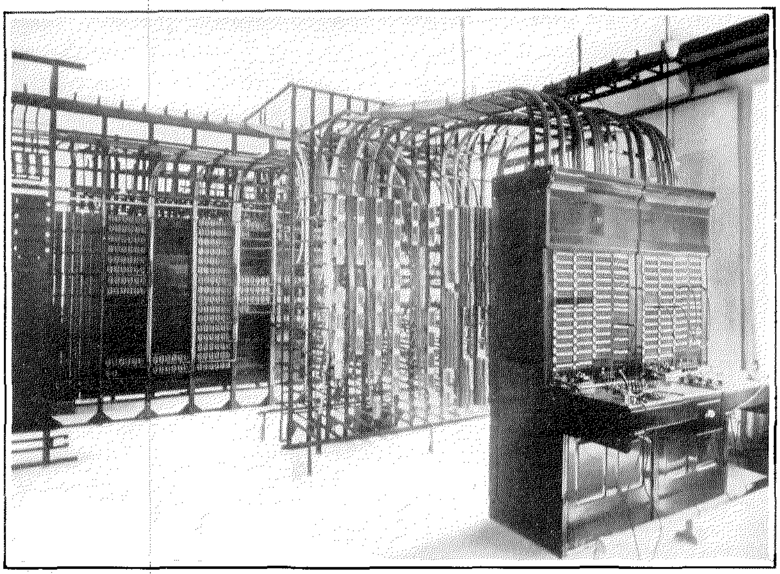


Figure 9—Toll Test Board, Distributing Frame and Repeating Coil Rack

the use of 500-cycle and 20-cycle tuned circuits, renders the panel immune from false operation due to voice current, also switch-hook and line disturbances. The vacuum tube employed has a very high amplification factor. This characteristic and the general arrangement of the circuit results in a very sensitive ringer. The panel will operate satisfactorily over a circuit of 15 TU. with a sending current of 2.0 milliamperes for the uninterrupted portions of the 500-cycle ringing current. The input impedance is very high and causes an inappreciable bridging loss to the circuit at all frequencies. In the case of 2-wire circuits it does not require balancing nor does it reduce the balance of the circuit to a noticeable extent. The filaments of the eight vacuum tubes of the ringing equipment are operated in series from the station 22½ volt battery. If any tube burns out, an alarm is operated and an equivalent resistance is inserted automatically in the place of its filament so that the operation of the remaining ringers is not affected.

The floor plan (Figure 12) illustrates the gen-

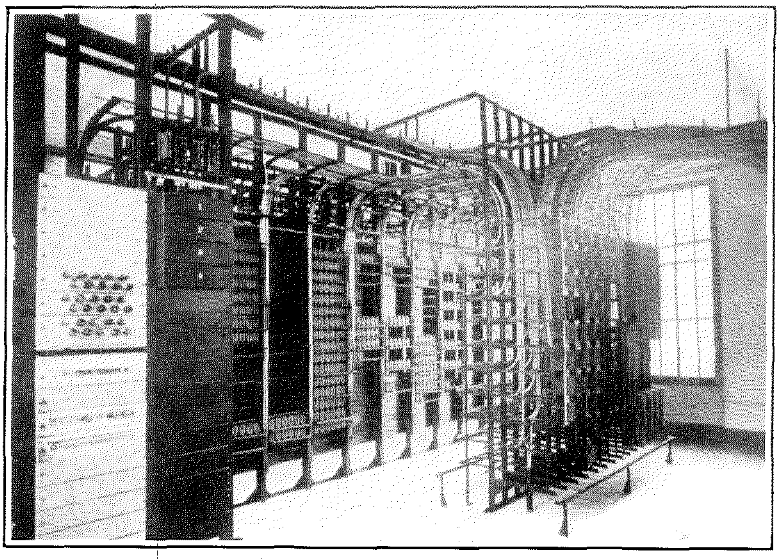


Figure 10—Fuse Panel, Distributing Frame and Repeating Coil Rack

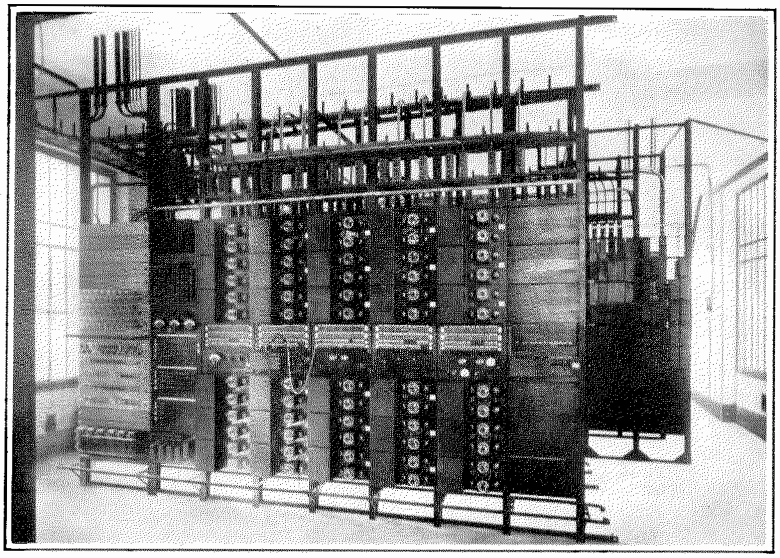


Figure 11—Four-wire Repeater Rack

eral arrangement of the repeater equipment. Figures 9, 10 and 11 show the equipment at a typical repeater station. The toll test board, combined distributing frame, and repeating coil rack are closely associated, so that the cable-runs from the point of entrance of the cable to the repeating coils may be as short as possible, in order to keep the danger of crosstalk between phantom and side circuits at a minimum. Adequate gangways are provided and space is reserved for future extensions. A transmission testing table is furnished and arranged to accommodate the portable transmission and impedance measuring apparatus used in making the line transmission tests and other special tests not provided for in the routine testing equipment of the station.

At all the stations, with one exception, outside power supply is available. Duplicate filament, plate and grid batteries are provided. For charging the filament batteries, ordinary commercial type generators are employed. With the aid of a noise filter especially developed for this purpose, it has been found possible to use commercial type machines for "floating" the filament batteries of repeater stations without appreciable noise on the toll circuits. As the twenty-four hour service drain is at present small, a "partial floating" routine is adopted. This routine consists in floating the battery on discharge during the day while the other battery is being charged. It secures the close regulation of voltage necessary for repeaters operating in tandem, together with economy in the size of cells and in power costs. In the case of the plate bat-

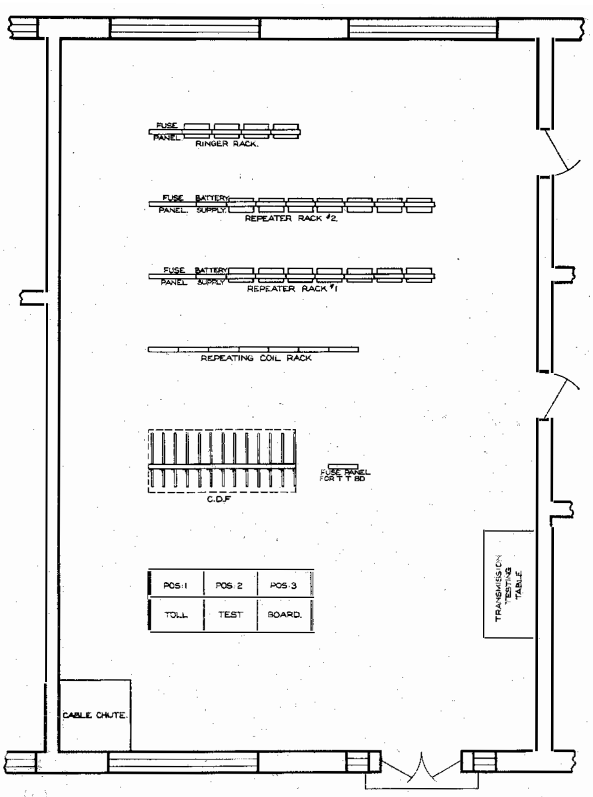


Figure 12—Repeater Station Apparatus Room Floor Plan

teries, a charge-discharge routine is employed. For charging the plate batteries, two generators are furnished. The grid batteries are charged from the filament battery through a suitable resistance.

Duplicate sets of 20-cycle ringing machines are provided at each station; and, in addition, at those stations where the voice frequency circuits terminate, duplicate sets of voice frequency ringing generators (500 cycle) are installed.

Figures 13, 14 and 15 show typical power plant arrangements.

In the case of the station at which no outside supply is available, all the batteries are operated on a charge and discharge routine. Two cold-starting heavy oil engine sets are installed and in order to compensate for variations in battery voltage an automatic filament current regulating device is provided at the station.

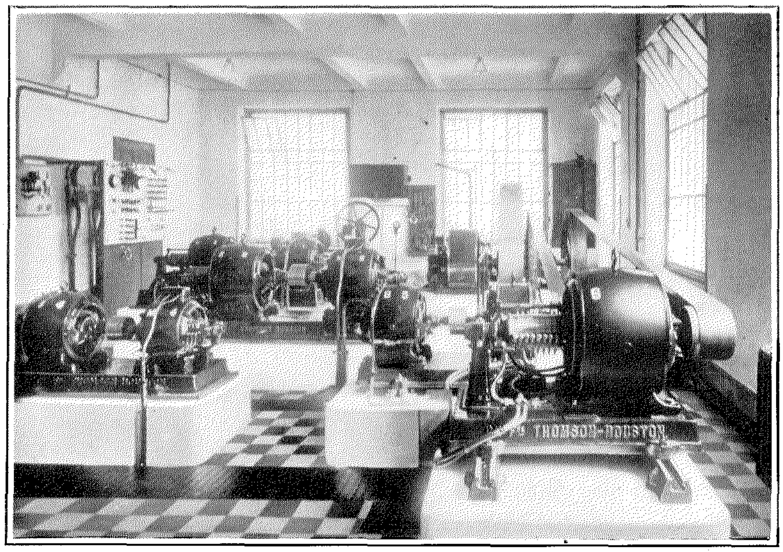


Figure 13—General View of Power Room

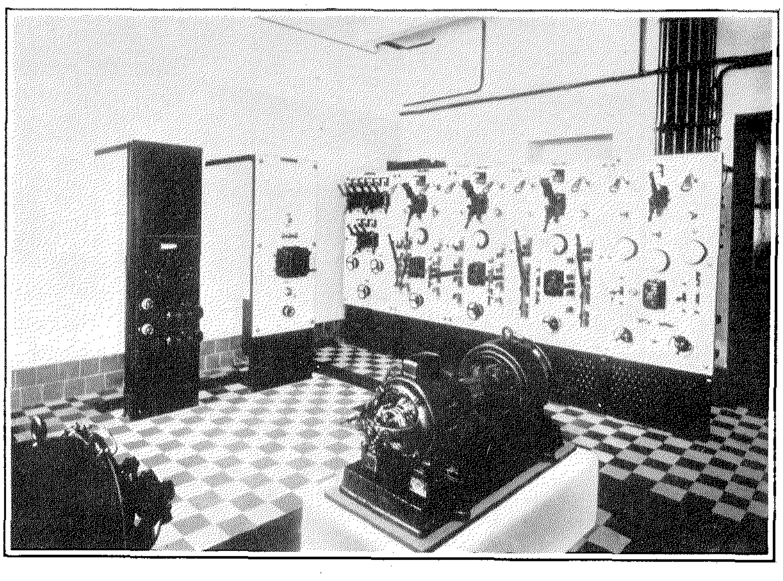


Figure 14—Power Board

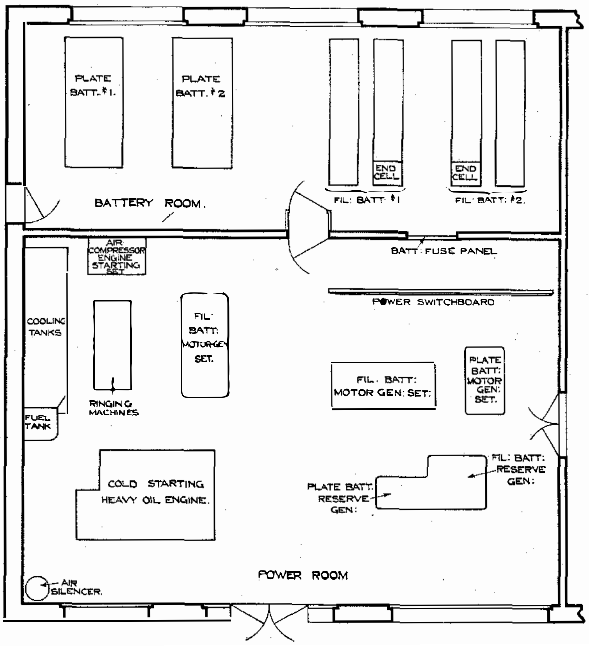


Figure 15—Floor Plan of Power and Battery Rooms

The repeater equipment was supplied and installed by Le Matériel Téléphonique acting as sub-contractors for Lignes Télégraphiques et Téléphoniques. The batteries are of Tudor manufacture while the motors and generators were made by the Compagnie des Téléphones Thomson-Houston. The oil engines were furnished by the Compagnie Française Nationale.

Transmission Tests

As soon as all the cabling and loading work on each repeater section was completed, a series of measurements was made to ensure that the cable and the loading coils were satisfactory and that the required degree of regularity had been obtained. A further object was to obtain transmission information for use during the setting up of the repeatered circuits. These tests, which included measurements of singing point, impedance, attenuation and crosstalk, are discussed briefly.

Toll line testing sets employed were, in most cases, similar to those described previously in "Electrical Communication."[2]

Singing Point

To determine the degree of impedance regularity obtained on the completed cable, the singing points of the circuits to be used for 2-wire working were measured from each end of each repeater section, the circuits having been balanced against the standard basic networks and building out condensers. Basic networks of each type giving average characteristics were chosen for the test, while the building out con-

[2] "Telephone Transmission Maintenance Practices," W. H. Capen, Electrical Communication, Vol. 3, April, 1925.

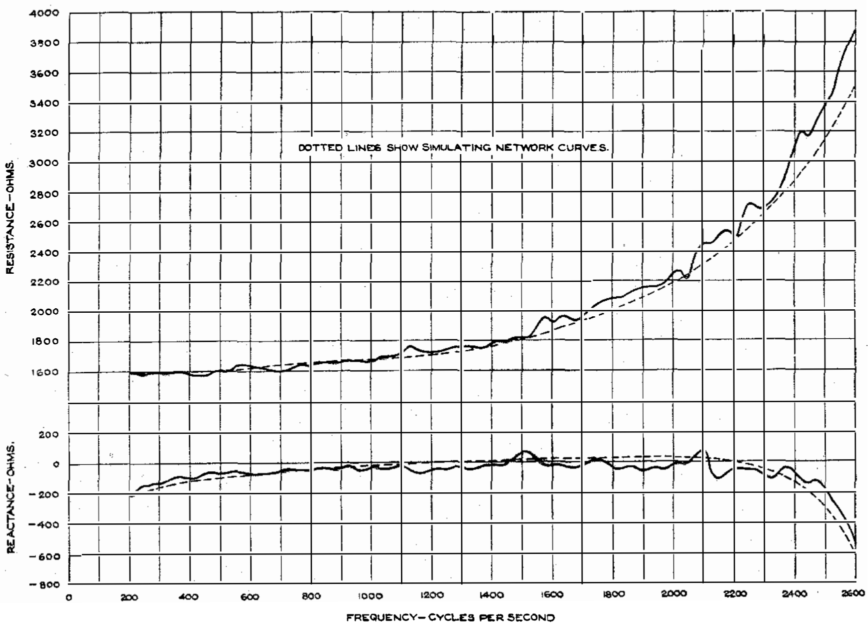


Figure 16—Impedance Curves—1.3 mm. H-177-107 Side Circuit

TABLE I

Summary of Singing Points
1.3 mm. H-177-107 2-Wire Circuits
(The values in this table are minimum values of singing point)

	Singing Points Measured with Impedance Unbalance Measuring Set Frequency Bands Cycles per Second												Measured with Singing Point Test Set	
	200–340		340–640		640–1200		1200–1700		1700–2260		2260–2400			
	TU	% Impedance Irregularity	TU	% Impedance Irregularity	TU	% Impedance Irregularity	TU	% Impedance Irregularity	TU	% Impedance Irregularity	TU	% Impedance Irregularity	TU	% Impedance Irregularity
Side Circuits														
Best Circuit......	38	3	33	4	33	4	28.5	8	27.5	9	28.5	8	31.5	5
Worst Circuit....	35	4	34	4	33	4	25.5	11	22.5	16	27.5	9	26.5	10
Phantom Circuits														
Best Circuit......	38	3	37	3	32	5	32	5	28.5	8	28.5	8	32.5	5
Worst Circuit....	38	3	32	5	29.5	7	28.5	8	25.5	11	22.5	16	28	8

TU = Transmission Units.

denser value was that which gave the highest average singing point.

These measurements were made by two distinct methods, using (1) a singing point test set and (2) an impedance unbalance measuring set. The first of these sets is similar in operation to a 21-type repeater and the results obtained with it are an indication of the degree of balance between the circuit under test and its balancing network. Since this set has similar filter effects, both at the low and high frequencies, to those in a 2-wire repeater, the readings which it gives are related closely to the maximum gain which such a repeater would give without singing when connected to the circuit under test and its balancing network. The impedance unbalance measuring set, on the other hand, enables the balance to be measured at any desired single frequency and yields results of a more fundamental nature than the singing point test set. Results from these tests are given in Table I.

(The figures for Percentage Impedance Irregularity refer to the radius of the circle as specified by the C. C. I. in Paris in June, 1925.)

Impedance

Impedance-frequency measurements were made by means of the 1-B line impedance bridge

TABLE II

Summary of Average 1000 *Cycle Attenuation at* 10° *C.*

Repeater Section	1.3 m/m H-177-107				0.9 m/m H-177-107				0.9 m/m H-44-25			
	Side		Phantom		Side		Phantom		Side		Phantom	
	β per Km.	TU per Km.	β per Km.	TU per Km.	β per Km.	TU per Km.	β per Km.	TU per Km.	β per Km.	TU per Km.	β per Km.	TU per Km.
1	.0113	.0982	.0093	.0808	.0200	.1737	.0162	.1407	.0346	.3005	.0288	.2502
2	.0113	.0982	.0094	.0816	.0199	.1729	.0165	.1433	.0346	.3005	.0288	.2502
3	.0112	.0973	.0093	.0808	.0200	.1737	.0165	.1433	.0346	.3005	.0288	.2502
4	.0114	.0990	.0094	.0816	.0199	.1729	.0165	.1433	.0346	.3005	.0288	.2502
5	.0114	.0990	.0095	.0825	.0200	.1737	.0164	.1425	.0346	.3005	.0288	.2502
6 & 7	.0113	.0982	.0093	.0808	.0198	.1720	.0162	.1407	.0344	.2988	.0287	.2493

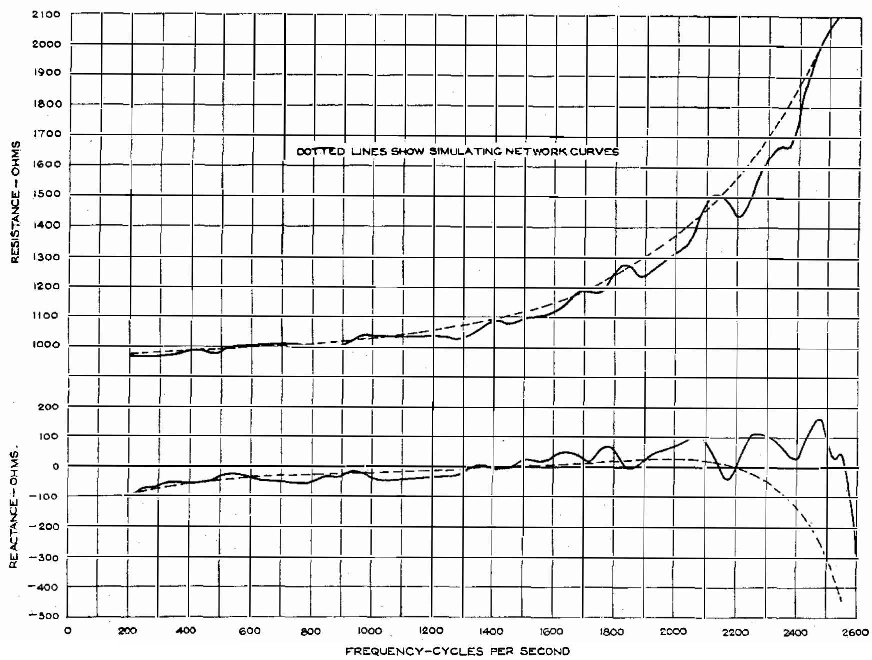


Figure 17—Impedance Curves—1.3 mm. H-177-107 Phantom Circuit

and the 4-B oscillator on representative circuits in each repeater section.

Figures 16 to 21, inclusive, show typical results of these measurements. In the first four figures, the corresponding balancing network impedance curves also are shown.

Attenuation

Measurements of attenuation at 1,000 cycles per second were made on a number of circuits in each repeater section. Table II gives a summary of these measurements corrected to 10° C., the mean ground temperature at the depth of the cable.

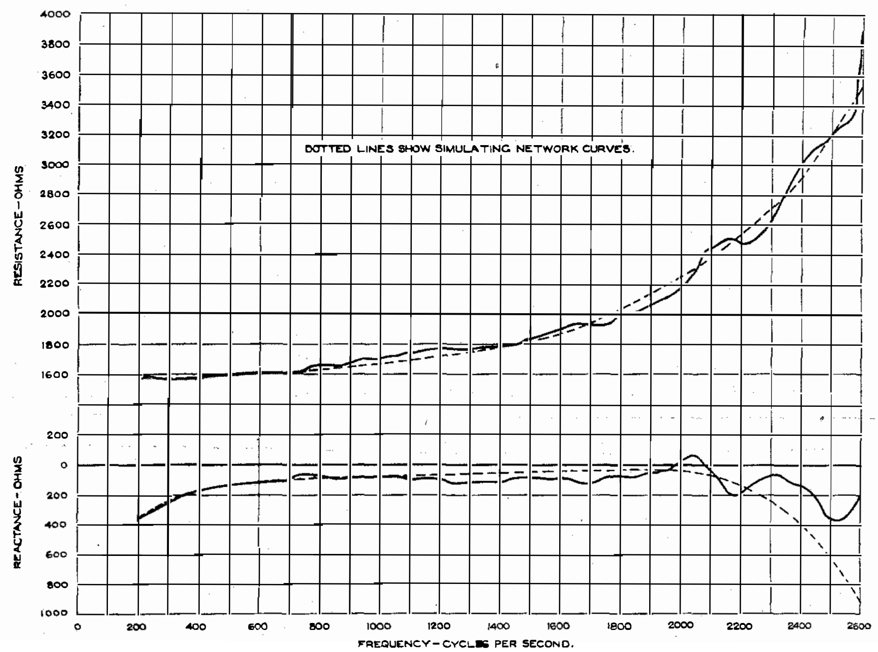


Figure 18—Impedance Curves—0.9 mm. H-177-107 Side Circuit

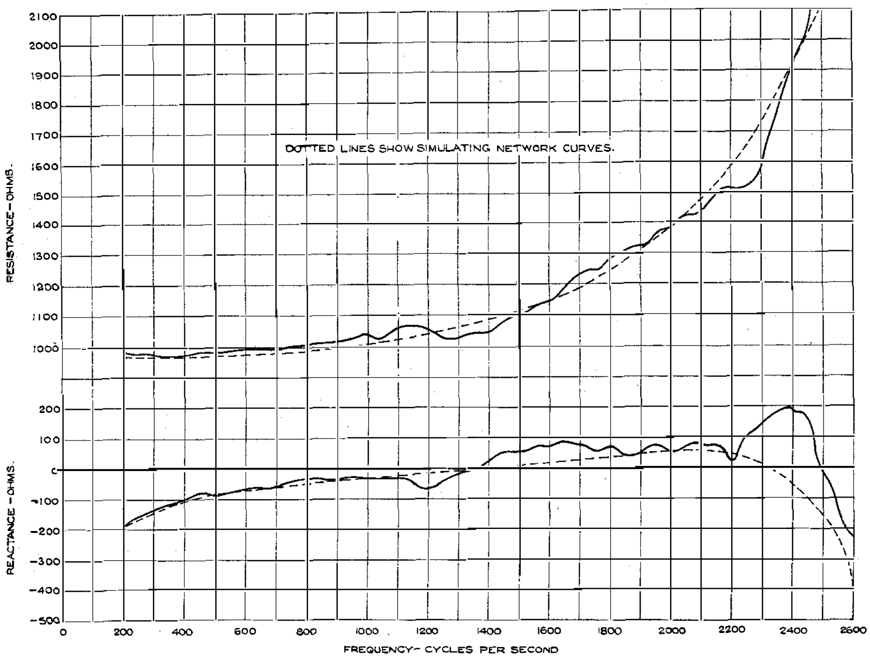


Figure 19—Impedance Curves—0.9 mm. H-177-107 Phantom Circuit

Figures 22, 23 and 24 show typical attenuation frequency curves.

Crosstalk

Crosstalk measurements were made on each repeater section, using a complex tone as the testing current. These tests were divided into "Near-end" and "Far-end". Near-end crosstalk measurements were made on all 2-wire circuits, the tone and the measuring set having been placed together first at one end of the repeater section and then at the other. Far-end measurements were made on all 4-wire circuits,

TABLE III

Near-End Crosstalk

1.3 mm. H-177-107 Circuits

Repeater Section	Crosstalk Within Quads								Crosstalk Between Quads			
	Phantom-Side				Side-Side				Phantom-Phantom			
	Average		Maximum		Average		Maximum		Average		Maximum	
	Cross-talk Units	$\beta 1$	Cross-talk Units	$\beta 1$	Cross-talk Units	$\beta 1$	Cross-talk Units	$\beta 1$	Cross-talk Units	$\beta 1$	Cross-talk Units	$\beta 1$
1	150	8.8	220	8.4	90	9.3	130	8.9	100	9.2	150	8.8
2	145	8.7	200	8.5	105	9.2	150	8.8	120	9.0	180	8.5
3	155	8.8	230	8.4	115	9.1	160	8.7	120	9.0	220	8.4
4	145	8.7	200	8.5	100	9.2	150	8.8	100	9.2	140	8.9
5	150	8.8	250	8.3	100	9.2	140	8.9	105	9.2	180	8.6
6 & 7	155	8.8	220	8.4	100	9.2	140	8.9	120	9.0	160	8.7

NOTE—The Average values given represent the average of the readings taken at both ends of each repeater section, while the maximum values represent the maximum reading for either end.

The values of $\beta 1$ given under the heading "Maximum" correspond to maximum values of crosstalk, and are therefore minimum values of $\beta 1$.

the tone and the measuring set having been placed at opposite ends of the repeater section. Results of these tests are summarized in Tables III and IV.

TABLE IV
Far-End Crosstalk

Repeater Section	Circuit Group	Phantom-Side				Side-Side				Phantom-Phantom			
		Average		Maximum		Average		Maximum		Average		Maximum	
		Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1
1 (82.84 km.)	0.9 mm. H-177-107	83	9.4	210	8.5	39	10.2	90	9.3	48	9.9	180	8.6
	0.9 mm. H-44-25	32	10.4	90	9.3	9	11.6	20	10.9	9	11.6	25	10.6
2 (73.86 km.)	0.9 mm. H-177-107	73	9.5	220	8.4	48	9.9	130	9.0	56	9.8	170	8.7
	0.9 mm. H-44-25	31	10.4	80	9.4	12	11.4	40	10.1	13	11.3	40	10.1
3 (81.35 km.)	0.9 mm. H-177-107	81	9.4	230	8.3	50	9.9	130	9.0	47	10.0	150	8.8
	0.9 mm. H-44-25	36	10.2	90	9.3	8	11.7	30	10.4	9	11.6	25	10.6
4 (83.20 km.)	0.9 mm. H-177-107	69	9.6	210	8.5	44	10.0	110	9.1	50	9.9	110	9.1
	0.9 mm. H-44-25	31	10.4	90	9.3	10	11.5	30	10.4	8	11.7	20	10.9
5 (80.18 km.)	0.9 mm. H-177-107	79	9.4	210	8.5	49	9.9	100	9.2	51	9.9	120	9.0
	0.9 mm. H-44-25	39	10.2	90	9.3	13	11.3	30	10.4	11	11.5	20	10.9
6 & 7 (91.91 km.)	0.9 mm. H-177-107	74	9.5	170	8.7	42	10.1	70	9.6	53	9.8	110	9.1
	0.9 mm. H-44-25	28	10.5	60	9.7	10	11.5	15	11.1	10	11.5	20	10.9

NOTE:—Typical crosstalk-frequency results are given in Figures 25 and 26.
The values of β1 given under the heading "Maximum" correspond to maximum values of crosstalk, and are therefore minimum values of β1.

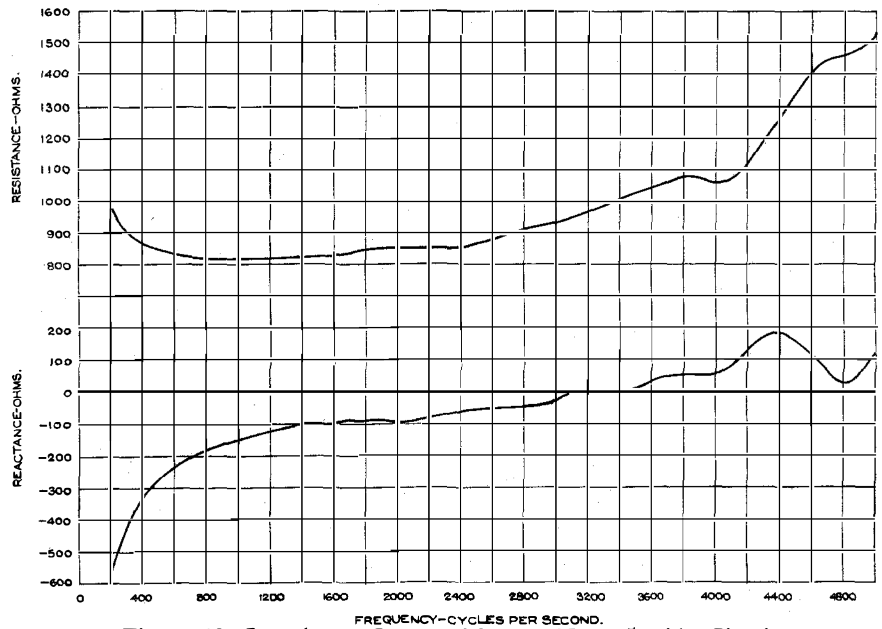


Figure 20—Impedance Curves—0.9 mm. H-44-25 Side Circuit

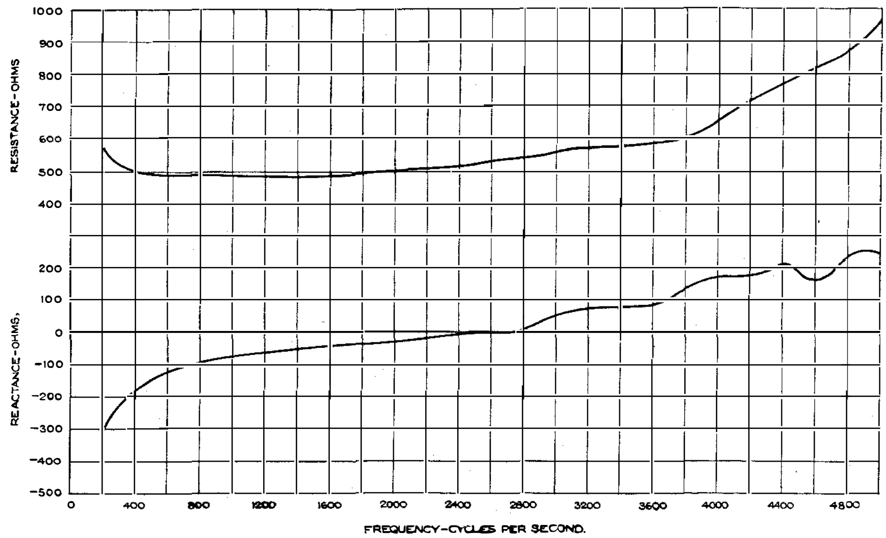


Figure 21—Impedance Curves—0.9 mm. H-44-25 Phantom Circuit

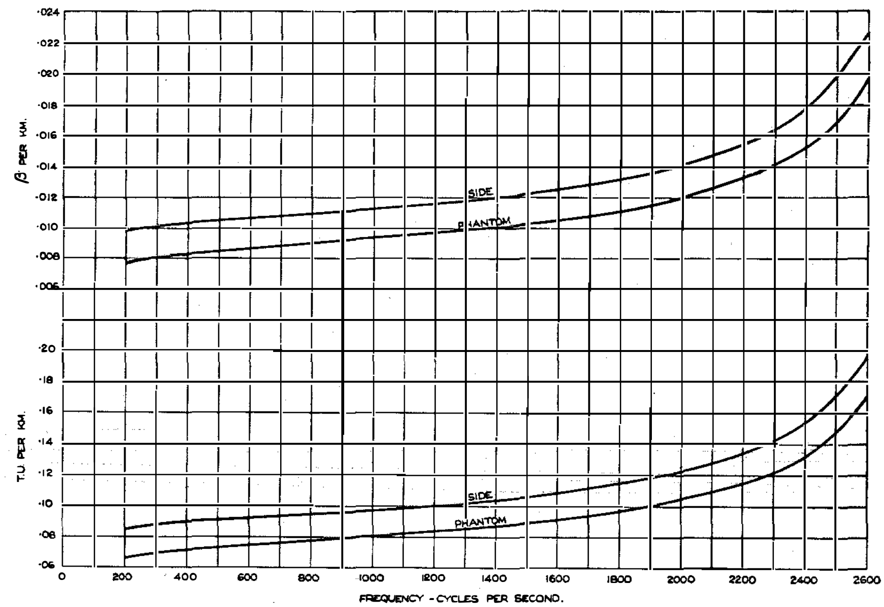


Figure 22—Attenuation—Frequency Curves—1.3 mm. H-177-107 Side and Phantom Circuits

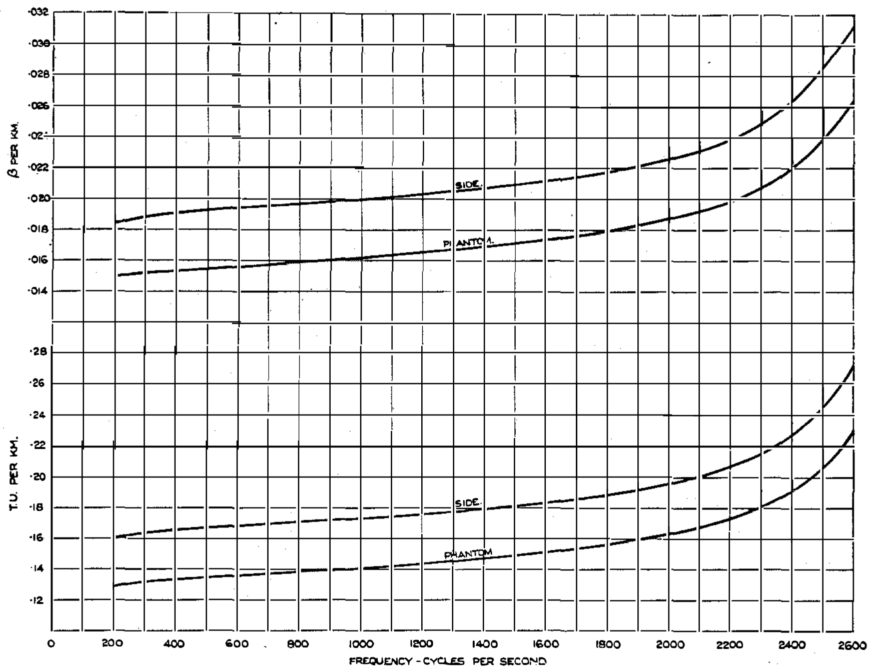


Figure 23—Attenuation—Frequency Curves—0.9 mm. H-177-107 Side and Phantom Circuits

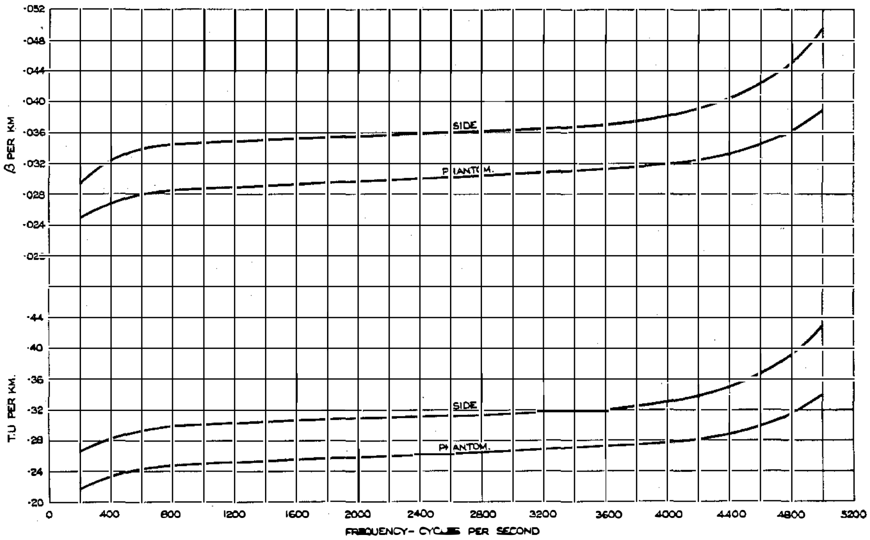


Figure 24—Attenuation—Frequency Curves—0.9 mm. H-44-25 Side and Phantom Circuits

TABLE V

Transmission Loss at 1000 Cycles per Second

Circuits	Direction	No. of Repeaters in Circuits	Type of Circuit	No. of Circuits	Transmission Loss					
					Maximum		Average		Minimum	
					β1	TU	β1	TU	β1	TU
Paris-Strasbourg......	West-East	4	4-wire 0.9 mm.	12	1.10	9.6	1.02	8.9	0.94	8.2
	East-West		H-177-107		1.07	9.3	0.93	8.1	0.85	7.4
Paris-Germany*......	West-East	7	4-wire 0.9 mm.	11	0.33	2.9	0.16	1.4	0.05	0.4
	East-West		H-44-25		0.26	2.3	0.16	1.4	0.07	0.6
Paris-Nancy.........	West-East	2	2-wire 1.3 mm.	9	1.07	9.3	0.98	8.5	0.87	7.6
	East-West		H-177-107		0.98	8.5	0.93	8.1	0.87	7.6
Strasbourg-Nancy.....	West-East	1	2-wire 0.9 mm.	6	1.43	12.4	1.33	11.6	1.09	9.5
	East-West		H-177-107		1.44	12.5	1.34	11.6	1.11	9.6
Paris-Reims*.........	West-East	1	2-wire 1.3 mm.	6	0.86	7.5	0.83	7.2	0.80	7.0
	East-West		H-177-107		0.82	7.1	0.80	6.9	0.76	6.6
Paris-Metz*..........	West-East	2	2-wire 1.3 mm.	9	1.10	9.6	0.96	8.3	0.83	7.2
	East-West		H-177-107		1.06	9.2	0.97	8.4	0.86	7.5
Strasbourg-Reims*....	West-East	2	2-wire 1.3 mm.	3	1.18	10.2	1.11	9.6	1.07	9.3
	East-West		H-177-107		1.09	9.5	1.05	9.1	0.95	8.3

*These values refer to the Paris-Strasbourg Cable portion of the circuit under operating conditions for the complete circuit.

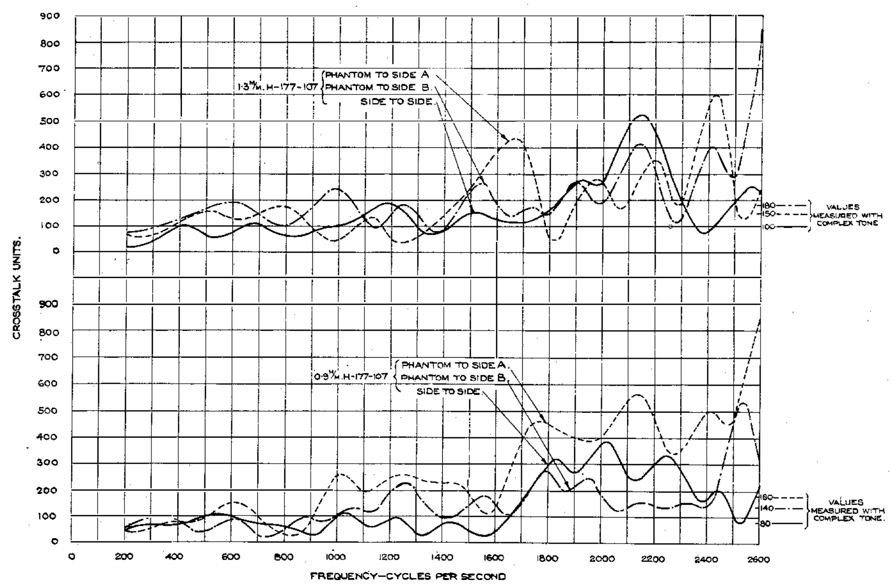


Figure 25—Near End Crosstalk—Voice Frequency—1.3 mm. and 0.9 mm. H-177-107 Circuits

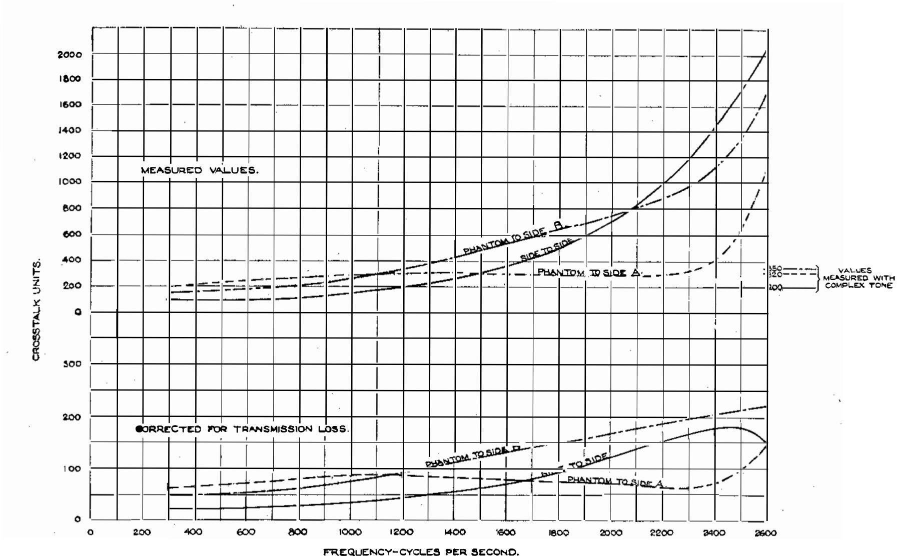


Figure 26—Far End Crosstalk—Voice Frequency—0.9 mm. H-177-107 Circuits

Overall Tests on Repeatered Circuits

All repeatered circuits, after having been set up for service, were tested for transmission loss and for crosstalk.

Transmission

Measurements of transmission loss at 1,000 cycles per second were made on all 2- and 4-wire circuits. Typical results are shown in Table V.

In addition, a number of circuits was tested for transmission frequency characteristics. Figures 27 to 30, inclusive, illustrate the results for typical circuits of each type.

From the curves shown in Figures 27 and 28, it will be observed that the transmission frequency characteristics of the 4-wire circuits when measured straight on the line were practically flat until the natural frequency of the line

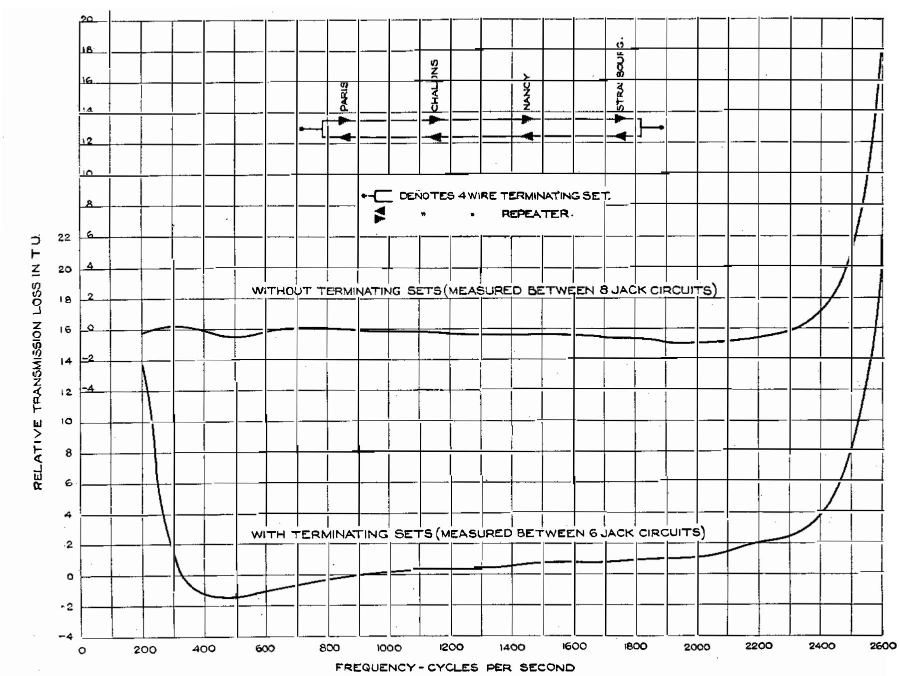


Figure 27—Overall Transmission Frequency Characteristics—0.9 mm. 4-wire H-177-107 Side Circuit

TABLE VI

Overall Crosstalk

	Crosstalk Within Quads								Crosstalk Between Quads			
	Phantom-Side				Side-Side				Phantom-Phantom			
	Average		Maximum		Average		Maximum		Average		Maximum	
	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1	Cross-talk Units	β1
FAR-END												
Paris-Strasbourg 4-wire 0.9 mm. H-177-107												
West-East	330	8.0	540	7.5	130	9.0	150	8.8	120	9.0	210	8.5
East-West	270	8.2	480	7.6	210	8.4	360	7.9	110	9.1	290	8.1
Paris-Germany* 4-wire 0.9 mm. H-44-25												
West-East	950	6.9	1500	6.5	250	8.3	330	8.0	200	8.5	350	7.9
East-West	870	7.0	1160	6.8	340	8.0	500	7.6	190	8.5	500	7.6
NEAR-END												
Paris-Nancy 2-wire 1.3 mm. H-177-107	450	7.7	900	7.0	250	8.3	250	8.3	170	8.7	500	7.6
Paris-Reims*	260	8.3	450	7.7	130	9.0	200	8.5	100	9.2	250	8.3

*These Values refer to the Paris-Strasbourg Cable portion of the circuit under operating conditions for the complete circuit.

was approached. This result was possible due to adjustment of repeater equalisation to compensate for rising line loss with increase in frequency.

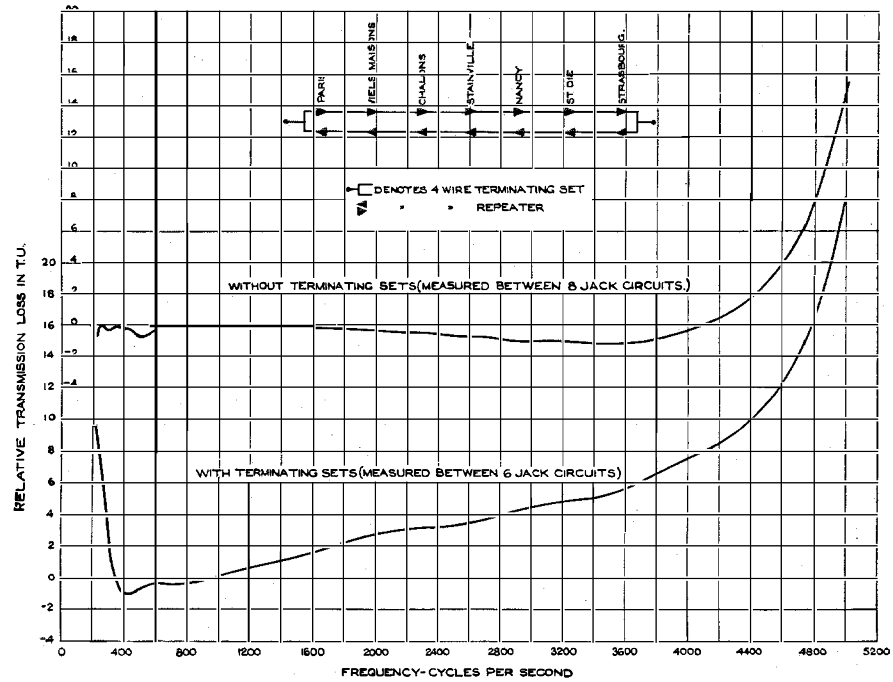


Figure 28—Overall Transmission Frequency Characteristics—0.9 mm. 4-wire H-44-25 Phantom Circuit

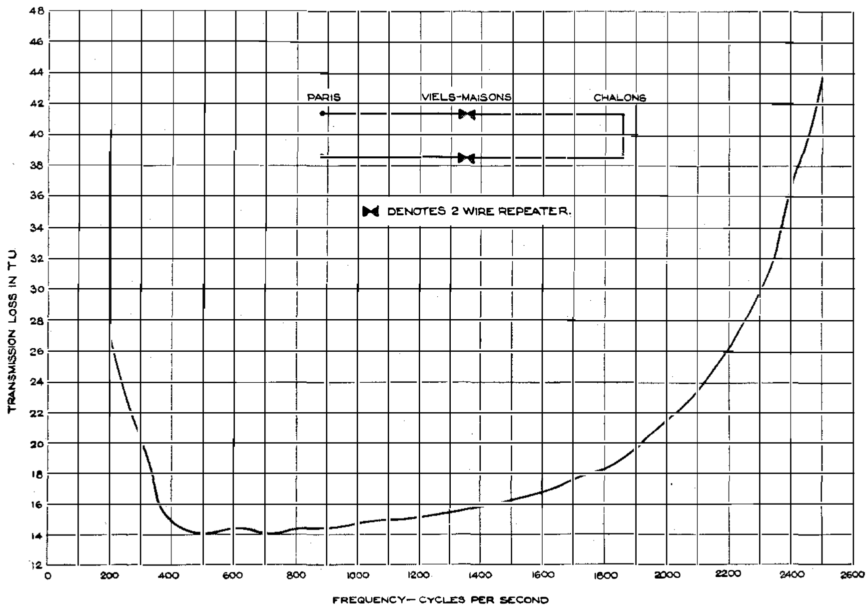


Figure 29—Overall Transmission Frequency Characteristics—1.3 mm. 2-wire H-177-107 Side Circuit

CROSSTALK

Measurements of near-end and far-end crosstalk were made on the 4-wire circuits under traffic conditions between Paris and Strasbourg.

Near-end crosstalk measurements were made on the 2-wire circuits under normal working conditions.

The results of these measurements are given in Table VI.

Conclusion

In this paper, it has been possible merely to touch briefly on the important technical features of the Paris-Strasbourg cable system. It is believed, however, that the facts enumerated are sufficient to show that the installation of this cable and its associated equipment has resulted not only in making available to France one of the most efficient toll systems in Europe but also in furnishing an important international link in the European communication network.

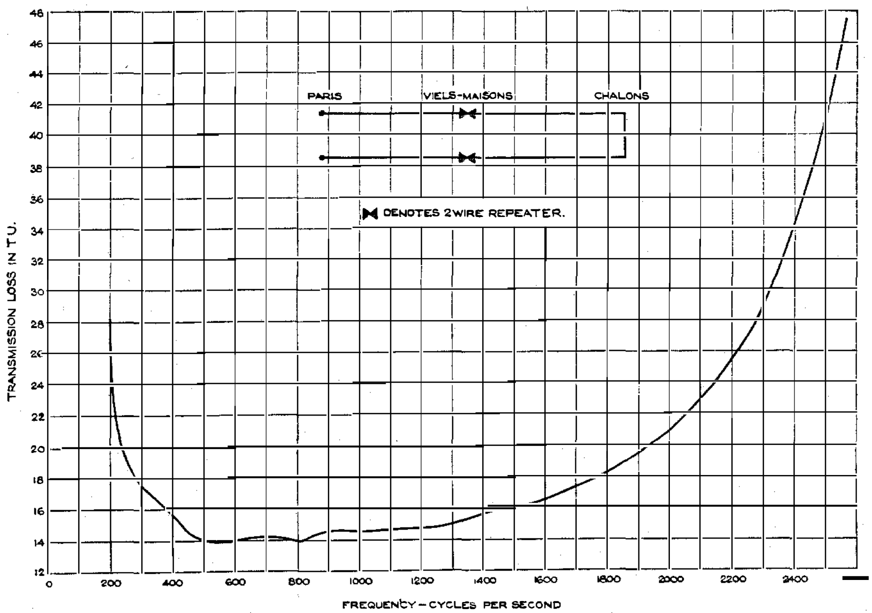
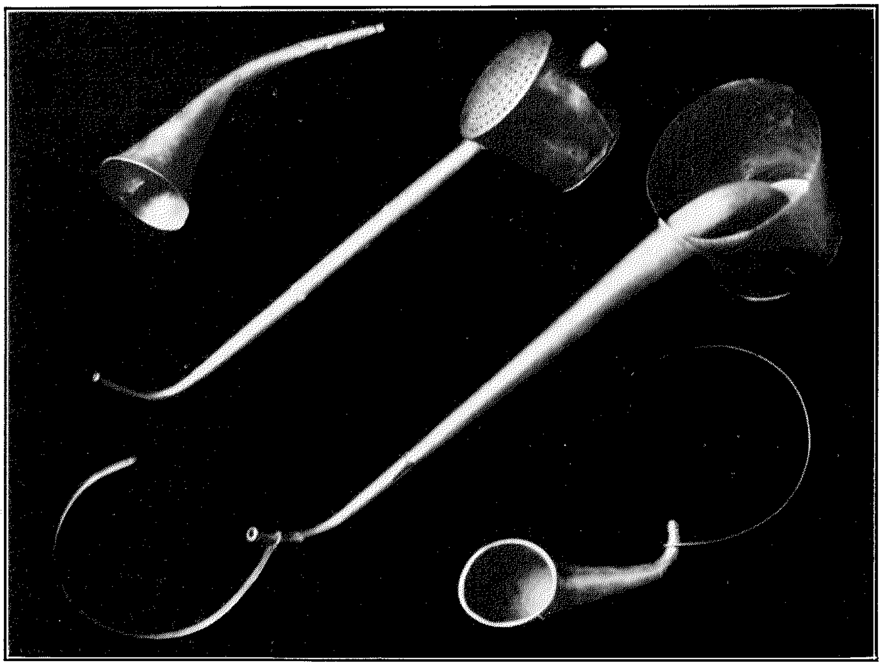


Figure 30—Overall Transmission Frequency Characteristics—1.3 mm. 2-wire H-177-107 Phantom Circuit

Beethoven's Ear-Trumpets

IN celebration of the Centenary of the great composer, the house in Bonn (Germany) where Beethoven was born has been visited this year by many musicians and others, and there has been an exhibition there of his portraits, musical instruments and manuscripts. and the shape of the trumpet in one instance is not unlike that of the horn of a loud-speaker.

Ludvig von Beethoven was born December 17, 1770, at Bonn. His father and grandfather were both professional musicians. Ludvig began to



Beethoven's Ear-trumpets, Exhibited at Bonn (Germany) on the Occasion of His Centenary, 1927

Melancholy interest attaches to the exhibits, amongst them of ear-trumpets employed by him in the vain endeavour to overcome his deafness. These devices were of brass. It is said that he used the smaller ones for ordinary conversational purposes, and the larger ones when trying to listen to music. The mode of attachment of the apparatus to the head resembles that now adopted for certain head-phones,

learn music at five years of age. He early studied Sebastian Bach's works, and at thirteen he published his own first composition. In 1809, just as he had been offered the post of Kapellmeister to the King of Westphalia, he was attacked by deafness—a malady which never left him. It became gradually worse and ended at last in complete loss of hearing. He died on March 26, 1827.

Telephone and Telegraph Statistics of the World

Compiled by Chief Statistician's Division American Telephone and Telegraph Company

Telephone Development of the World, by Countries
January 1, 1926

	Number of Telephones			Per Cent of Total World	Telephones per 100 Population	Increase in Number of Telephones During 1925
	Government Systems	Private Companies	Total			
NORTH AMERICA:						
United States	—	16,935,918	16,935,918	60.96%	14.8	863,160
Canada	208,982	935,113	1,144,095	4.12%	12.2	71,641
Central America	8,556	11,458	20,014	.07%	0.3	2,084
Mexico	2,091	52,374	54,465	.20%	0.4	3,485
West Indies:						
Cuba	545	61,569	62,114	.22%	1.8	7,200
Porto Rico	806	11,954	12,760	.05%	0.9	646
Other W. I. Places*	6,340	11,535	17,875	.06%	0.3	2,614
Other No. American Places*	85	3,936	4,021	.01%	1.1	213
Total	227,405	18,023,857	18,251,262	65.69%	11.6	951,043
SOUTH AMERICA:						
Argentina	—	189,036	189,036	.66%	1.9	15,431
Bolivia†	—	1,824	1,824	.01%	0.1	—
Brazil	632	102,352	102,984	.37%	0.3	4,420
Chile	—	35,164	35,164	.13%	0.8	4,269
Colombia	50	17,292	17,342	.06%	0.2	2,419
Ecuador†	1,691	2,827	4,518	.02%	0.2	—
Paraguay†	183	278	461	.01%	0.04	—
Peru	—	11,000	11,000	.04%	0.2	1,448
Uruguay	—	26,051	26,051	.10%	1.6	810
Venezuela	560	11,495	12,055	.04%	0.4	1,008
Other Places	2,642	—	2,642	.01%	0.5	115
Total	5,758	397,319	403,077	1.45%	0.5	29,920
EUROPE:						
Austria	153,043	—	153,043	.55%	2.3	7,902
Belgium	159,072	—	159,072	.57%	2.0	22,128
Bulgaria*	9,000	—	9,000	.03%	0.2	903
Czechoslovakia	120,548	—	120,548	.43%	0.9	4,810
Denmark	13,281#	303,116	316,397	1.14%	9.2	8,420
Finland	—	85,000	85,000	.31%	2.4	2,000
France	737,198	—	737,198	2.65%	1.8	77,071
Germany	2,588,016	—	2,588,016	9.31%	4.1	202,839
Great Britain and No. Ireland	1,379,656	—	1,379,656	4.97%	3.0	115,632
Greece*	5,500	—	5,500	.02%	0.1	50
Hungary	78,451	—	78,451	.28%	0.9	−161
Irish Free State (March 31, 1926)	21,853	—	21,853	.08%	0.7	212
Italy (June 30, 1926)*	—	200,000	200,000	.72%	0.5	18,000
Jugo-Slavia	29,942	—	29,942	.11%	0.2	2,000
Latvia (March 31, 1926)	18,843	—	18,843	.07%	1.0	3,286
Netherlands	214,041	—	214,041	.77%	2.9	11,173
Norway	100,955‡	72,797	173,752	.63%	6.3	5,234
Poland	68,221	52,009	120,230	.43%	0.4	8,559
Portugal	2,500*	18,456	20,956	.08%	0.3	1,200
Roumania	41,755	—	41,755	.15%	0.2	7,175
Russia§	192,782	—	192,782	.69%	0.1	30,000
Spain*	—	113,000	113,000	.41%	0.5	8,000
Sweden	434,594	1,746	436,340	1.57%	7.2	18,022
Switzerland	195,525	—	195,525	.70%	5.0	6,096
Other Places in Europe*	54,750	14,040	68,790	.25%	0.8	6,000
Total	6,619,526	860,164	7,479,690	26.92%	1.5	566,551
ASIA:						
British India (March 31, 1926)	15,050	28,189	43,239	.16%	0.01	1,999
China*	82,168	35,606	117,774	.43%	0.03	5,704
Japan (March 31, 1926)	636,736	—	636,736	2.29%	1.1	92,303
Other Places in Asia*	100,883	7,954	108,837	.39%	0.1	4,172
Total	834,837	71,749	906,586	3.27%	0.1	104,178
AFRICA:						
Egypt	35,744	—	35,744	.13%	0.2	1,936
Union of South Africa#	80,689	—	80,689	.29%	1.1	9,241
Other Places in Africa*	52,929	1,086	54,015	.19%	0.05	5,768
Total	169,362	1,086	170,448	.61%	0.1	16,945
OCEANIA:						
Australia (June 30, 1925)	362,949	—	362,949	1.30%	6.1	44,670
Dutch East Indies	37,561	3,402	40,963	.15%	0.01	1,694
Hawaii	—	18,804	18,804	.07%	6.4	1,097
New Zealand (March 31, 1926)	130,186	—	130,186	.47%	9.2	10,089
Philippine Islands	4,517	12,449	16,966	.06%	0.1	1,000
Other Places in Oceania*	2,502	530	3,032	.01%	0.2	278
Total	537,715	35,185	572,900	2.06%	0.8	58,828
TOTAL WORLD	8,394,603	19,389,360	27,783,963	100.00%	1.5	1,727,465

* Partly estimated.
\# March 31, 1926.
‡ June 30, 1925.
§ Including Siberia and Associated Republics.
† January 1, 1925.

Telephone and Telegraph Wire of the World, by Countries

January 1, 1926

	Miles of Telephone Wire				Miles of Telegraph Wire		
	Service Operated by (See Note)	Number of Miles	Per Cent of Total World	Per 100 Population	Number of Miles	Per Cent of Total World	Per 100 Population
NORTH AMERICA:							
United States	P.	52,200,000	60.72%	45.5	2,035,000	30.49%	1.8
Canada	P.G.	3,048,647	3.55%	32.6	284,121	4.26%	3.0
Central America	P.G.	37,511	.04%	0.6	19,902	.30%	0.3
Mexico	P.G.	126,645	.15%	0.8	81,876	1.23%	0.5
West Indies:							
Cuba	P.G.	188,949	.22%	5.5	10,939	.16%	0.3
Porto Rico	P.G.	25,196	.03%	1.8	1,067	.01%	0.1
Other W. I. Places*	P.G.	37,244	.04%	0.6	5,550	.08%	0.1
Other No. American Places*	P.G.	8,042	.01%	2.3	10,000	.15%	2.8
Total		55,672,234	64.76%	35.5	2,448,455	36.68%	1.6
SOUTH AMERICA:							
Argentina	P.	593,221	.69%	5.9	200,442	3.00%	2.0
Bolivia	P.	3,589†	.01%	0.1	6,986	.11%	0.2
Brazil	P.G.	265,861	.31%	0.7	97,034	1.45%	0.3
Chile	P.	53,116	.06%	1.1	45,116	.68%	1.0
Colombia	P.	22,656	.02%	0.3	15,538	.23%	0.2
Ecuador	P.G.	5,083†	.01%	0.2	4,555	.07%	0.2
Paraguay	P.G.	138†	—	0.01	2,223	.03%	0.2
Peru	P.	39,433	.04%	0.7	10,691	.16%	0.2
Uruguay	P.	46,677	.05%	2.8	6,404	.10%	0.4
Venezuela	P.G.	31,589	.04%	1.1	6,883	.10%	0.2
Other Places	G.	4,713	.01%	1.0	779	.01%	0.2
Total		1,066,076	1.24%	1.4	396,651	5.94%	0.5
EUROPE:							
Austria	G.	401,498	.47%	5.9	48,135	.72%	0.7
Belgium	G.	600,246	.70%	7.7	25,733	.39%	0.3
Bulgaria*	G.	35,000	.04%	0.7	20,000	.30%	0.4
Czechoslovakia	G.	231,805	.27%	1.6	44,298	.66%	0.3
Denmark	P.G.	771,927	.90%	22.4	9,064	.14%	0.3
Finland	P.	108,887	.13%	3.1	9,758	.15%	0.3
France	G.	2,058,832	2.39%	5.1	474,228	7.10%	1.2
Germany	G.	8,603,015	10.00%	13.5	558,987	8.37%	0.9
Great Britain and No. Ireland#	G.	5,618,346	6.53%	12.4	327,890	4.91%	0.7
Greece*	G.	7,000	.01%	0.1	30,000	.45%	0.5
Hungary	G.	239,428	.28%	2.9	51,468	.77%	0.6
Irish Free State (March 31, 1926)	G.	60,551	.07%	2.0	22,983	.34%	0.8
Italy (June 30, 1926)*	P.G.	650,000	.76%	1.6	264,000	3.96%	0.7
Jugo-Slavia	G.	86,802	.10%	0.6	55,484	.83%	0.4
Latvia (March 31, 1926)	G.	91,298	.11%	4.8	5,996	.09%	0.3
Netherlands	G.	440,000*	.51%	5.9	28,818	.43%	0.4
Norway (June 30, 1925)	P.G.	441,591	.51%	15.9	25,067	.38%	0.9
Poland	P.G.	453,712	.53%	1.6	60,005	.90%	0.2
Portugal	P.G.	69,355	.08%	1.1	19,500*	.29%	0.3
Roumania	G.	91,350	.11%	0.5	50,757	.76%	0.3
Russia‡	G.	898,137	1.04%	0.6	382,709	5.73%	0.3
Spain*	P.	225,000	.26%	1.0	83,000	1.24%	0.4
Sweden	G.	979,957	1.14%	16.2	54,503	.82%	0.9
Switzerland	G.	539,059	.63%	13.7	24,674	.37%	0.6
Other Places in Europe*	P.G.	132,786	.15%	1.6	15,813	.24%	0.2
Total		23,835,582	27.72%	4.7	2,692,870	40.34%	0.5
ASIA:							
British India (March 31, 1926)	P.G.	348,115	.40%	0.1	392,660	5.89%	0.1
China*	P.G.	194,739	.23%	0.04	84,847	1.27%	0.02
Japan (March 31, 1926)	G.	1,868,842	2.17%	3.1	176,339	2.64%	0.3
Other Places in Asia*	P.G.	220,829	.26%	0.2	110,254	1.65%	0.1
Total		2,632,525	3.06%	0.3	764,100	11.45%	0.1
AFRICA:							
Egypt	G.	134,334	.16%	0.7	26,973	.41%	0.1
Union of South Africa#	G.	283,290*	.33%	3.8	45,830	.69%	0.6
Other Places in Africa*	P.G.	107,032	.12%	0.1	129,105	1.93%	0.1
Total		524,656	.61%	0.4	201,908	3.03%	0.1
OCEANIA:							
Australia (June 30, 1925)	G.	1,526,699	1.77%	25.7	114,048	1.71%	1.9
Dutch East Indies	P.G.	183,810	.21%	0.3	20,032	.30%	0.04
Hawaii	P.	58,221	.07%	19.9	0	.00%	0.0
New Zealand (March 31, 1926)	G.	436,410	.51%	31.0	25,814	.39%	1.8
Philippine Islands	P.G.	33,906	.04%	0.3	9,521	.14%	0.8
Other Places in Oceania*	P.G.	5,469	.01%	0.3	1,351	.02%	0.1
Total		2,244,515	2.61%	3.0	170,766	2.56%	0.2
TOTAL WORLD		85,975,588	100.00%	4.6	6,674,750	100.00%	0.4

Note: Telegraph service is operated by Governments, except in the United States and Canada. In connection with telephone wire, P. indicates telephone service operated by private companies, G. by the Government, and P.G. by both private companies and the Government.

* Partly estimated. # March 31, 1926. ‡ Including Siberia and Associated Republics. † January 1, 1925.

Telephone Development of Large and Small Communities

January 1, 1926

Country	Service Operated by (See Note)	Number of Telephones: In Communities of 50,000 Population and Over	Number of Telephones: In Communities of less than 50,000 Population	Telephones per 100 Population: In Communities of 50,000 Population and Over	Telephones per 100 Population: In Communities of less than 50,000 Population
Austria	G.	112,664	40,379	5.0	0.9
Belgium	G.	117,879	41,193	3.8	0.9
Canada	P.G.	528,166	615,929	20.6	9.1
Czechoslovakia	G.	44,913	75,635	4.0	0.6
Denmark	P.G.	137,472	178,925	15.6	7.0
France	G.	426,955	310,243	5.0	1.0
Germany	G.	1,571,361	1,016,655	7.8	2.3
Great Britain and Northern Ireland#	G.	1,032,433	379,027	4.4	1.7
Japan#	G.	383,077	253,659	3.8	0.5
Netherlands	G.	139,924	74,117	5.4	1.5
New Zealand#	G.	46,524	83,662	9.0	9.4
Norway	P.G.	55,917	117,835	13.7	5.0
Poland	P.G.	63,913	56,317	2.2	0.2
Sweden	G.	162,964	273,376	19.4*	5.2
Switzerland	G.	85,760	109,765	11.1	3.5
United States	P.	8,659,943	8,275,975	19.8	11.7

Note: P. Indicates telephone service operated by Private Companies, G. by the Government, and P.G. by both Private Companies and the Government.

March 31, 1926.

* The majority of this development is due to Stockholm.

Telephones in United States—Distribution by States

January 1, 1926 and January 1, 1927

State	Number of Telephones January 1, 1926	Number of Telephones January 1, 1927	State	Number of Telephones January 1, 1926	Number of Telephones January 1, 1927
Alabama	109,512	115,451	Nevada	11,720	12,262
Arizona	29,728	31,727	New Hampshire	79,195	81,485
Arkansas	113,667	117,414	New Jersey	512,048	558,211
California	1,027,552	1,126,387	New Mexico	19,921	20,854
Colorado	170,575	176,906	New York	2,292,650	2,442,298
Connecticut	256,813	275,169	North Carolina	142,738	151,455
Delaware	26,406	27,617	North Dakota	83,276	84,291
District of Columbia	127,977	137,327	Ohio	1,054,426	1,078,379
Florida	127,594	158,065	Oklahoma	256,719	270,053
Georgia	158,440	166,421	Oregon	169,613	178,597
Idaho	51,617	53,748	Pennsylvania	1,281,314	1,333,219
Illinois	1,522,959	1,603,271	Rhode Island	106,706	111,775
Indiana	535,426	536,671	South Carolina	60,708	62,911
Iowa	566,085	564,343	South Dakota	110,119	110,841
Kansas	380,509	387,772	Tennessee	203,289	215,813
Kentucky	223,444	220,105	Texas	557,889	590,106
Louisiana	118,969	130,485	Utah	59,423	61,060
Maine	127,030	128,622	Vermont	58,357	59,854
Maryland	180,826	191,752	Virginia	170,637	177,551
Massachusetts	808,194	843,170	Washington	271,453	286,135
Michigan	631,141	675,568	West Virginia	141,027	142,091
Minnesota	455,451	460,394	Wisconsin	482,353	499,890
Mississippi	71,543	76,502	Wyoming	27,471	27,410
Missouri	620,492	642,092			
Montana	56,221	56,870			
Nebraska	284,695	285,778	United States	16,935,918	17,746,168

Telephone Conversations and Telegrams

Year 1925

Country	Number of Telephone Conversations	Number of Telegrams	Total Number of Wire Communications	Per Cent of Total Wire Communications: Telephone Conversations	Per Cent of Total Wire Communications: Telegrams	Wire Communications Per Capita: Telephone Conversations	Wire Communications Per Capita: Telegrams	Wire Communications Per Capita: Total
Australia	295,380,000	17,773,000	313,153,000	94.3	5.7	50.4	3.0	53.4
Austria	366,730,000	3,675,000	370,405,000	99.0	1.0	54.7	0.6	55.3
Belgium	146,573,000	5,574,000	152,147,000	96.3	3.7	18.9	0.7	19.6
Czechoslovakia	191,572,000	5,141,000	196,713,000	97.4	2.6	13.5	0.4	13.9
Denmark	460,875,000	2,368,000	463,243,000	99.5	0.5	134.6	0.7	135.3
France	788,302,000	59,143,000	847,445,000	93.0	7.0	19.6	1.5	21.1
Germany	2,038,499,000	40,295,000	2,078,794,000	98.1	1.9	32.5	0.6	33.1
Gt. Britain and No. Ireland#	1,127,353,000	60,347,000	1,187,700,000	95.0	5.0	25.0	1.3	26.3
Hungary	110,721,000	4,950,000	115,671,000	95.7	4.3	13.4	0.6	14.0
Italy (1923)	361,351,000	18,457,000	379,808,000	95.1	4.9	9.0	0.5	9.5
Japan	1,964,253,000	61,585,000	2,025,838,000	97.0	3.0	33.0	1.0	34.0
Netherlands	396,319,000	5,460,000	401,779,000	98.6	1.4	53.8	0.7	54.5
Norway	295,026,000	4,094,000	299,120,000	98.6	1.4	106.8	1.5	108.3
Sweden	642,658,000	3,937,000	646,593,000	99.4	0.6	106.3	0.7	107.0
Switzerland	154,690,000	3,126,000	157,816,000	98.0	2.0	39.4	0.8	40.2
United States	22,400,000,000	215,000,000	22,615,000,000	99.0	1.0	196.4	1.9	198.3

Note: Telephone conversations include local and toll or long distance conversations. Number of telephone conversations in the United States includes completed messages only.

Telephone Development of Large Cities
January 1, 1926

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
ARGENTINA:			
Buenos Aires	2,310,000	104,281	4.5
AUSTRALIA:			
Adelaide	304,000	24,838	8.2
Brisbane	264,000	18,477	7.0
Melbourne	912,000	73,694	8.1
Sydney	1,039,000	87,504	8.4
AUSTRIA:			
Gratz	157,000	7,146	4.6
Vienna	1,919,000	98,226	5.1
BELGIUM:			
Antwerp	490,000	23,379	4.8
Brussels	892,000	54,798	6.1
Charleroi	184,000	4,832	2.6
Ghent	268,000	6,696	2.5
Liege	408,000	11,331	2.8
CANADA:			
Montreal	821,000	138,225	16.8
Ottawa	180,000	33,547	18.6
Toronto	633,000	154,740	24.5
CHINA*			
Canton	925,000	3,000	0.3
Shanghai	1,560,000	24,000	1.5
Tientsin	830,000	7,770	0.9
Peking	1,350,000	41,294	3.1
CUBA:			
Havana	563,000	42,860	7.6
CZECHOSLOVAKIA:			
Prague	704,000	29,049	4.1
DANZIG, FREE CITY OF	373,000	17,497	4.7
DENMARK:			
Copenhagen	755,000	121,286	16.1
FRANCE:			
Bordeaux	276,000	12,579	4.6
Lille	207,000	9,883	4.8
Lyons	580,000	18,501	3.2
Marseilles	605,000	18,528	3.1
Paris	2,995,000	255,561	8.5
GERMANY:			
Berlin	4,034,000	415,871	10.3
Bremen	296,000	27,161	9.2
Breslau	558,000	36,486	6.5
Chemnitz	334,000	20,785	6.2
Cologne	701,000	57,563	8.2
Dresden	622,000	50,139	8.1
Dusseldorf	433,000	33,919	7.8
Essen	471,000	21,273	4.5
Frankfort-on-Main	464,000	50,980	11.0
Hamburg-Altona	1,270,000	139,107	11.0
Hannover	424,000	30,897	7.3
Leipzig	682,000	57,586	8.4
Magdeburg	293,000	18,892	6.4
Munich	696,000	61,537	8.8
Nuremburg	468,000	30,633	6.5
Stuttgart	343,000	34,538	10.1
GREAT BRITAIN AND NORTH IRELAND: (March 31, 1926)			
Belfast	415,000	12,371	3.0
Birmingham	1,069,000	37,394	3.5
Blackburn	127,000	3,697	2.9
Bolton	179,000	4,655	2.6
Bradford	314,000	15,100	4.8
Bristol	390,000	13,647	3.5
Edinburgh	420,000	21,372	5.1
Glasgow	1,119,000	45,957	4.1
Hull	341,000	14,904	4.4
Leeds	482,000	16,742	3.5
Liverpool	1,116,000	46,556	4.2
London	7,406,000	488,499	6.6
Manchester	1,055,000	49,944	4.7
Newcastle	458,000	15,961	3.5
Nottingham	293,000	11,955	4.1
Plymouth	210,000	4,820	2.3
Sheffield	491,000	15,019	3.1

* Partly estimated.

Telephone Development of Large Cities—(*Concluded*)
January 1, 1926

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
HUNGARY: (January 1, 1925)			
Budapest	953,000	48,680	5.1
Szegedin	113,000	2,083	1.8
IRISH FREE STATE: (March 31, 1926)			
Dublin	406,000	12,917	3.2
ITALY: (June 30, 1923)			
Milan	714,000	17,992	2.5
Naples	785,000	6,786	0.9
Rome	648,000	14,261	2.2
Turin	509,000	7,953	1.6
JAPAN: (March 31, 1926)			
Kobe	652,000	24,642	3.8
Kyoto	698,000	24,181	3.5
Nagoya	802,000	21,629	2.7
Osaka	1,187,000	76,845	6.5
Tokio	2,069,000	121,856	5.9
Yokohama	412,000	13,456	3.3
LATVIA: (March 31, 1926)			
Riga	340,000	10,624	3.1
NETHERLANDS:			
Amsterdam	718,000	39,644	5.5
The Hague	398,000	29,070	7.3
Rotterdam	552,000	32,323	5.9
NEW ZEALAND: (March 31, 1926)			
Auckland	193,000	14,655	7.6
Christchurch	118,000	10,055	8.5
Wellington	122,000	14,656	12.0
NORWAY: (June 30, 1925)			
Oslo	254,000	39,682	15.6
POLAND:			
Warsaw	960,000	36,314	3.8
ROUMANIA:			
Bucharest*	365,000	11,730	3.2
RUSSIA:			
Kazan	170,000	1,566	0.9
Kharkov	388,000	4,800	1.2
Leningrad	1,511,000	38,418	2.5
Moscow	1,913,000	48,378	2.5
Odessa	390,000	2,598	0.7
SPAIN:			
Barcelona	710,000	18,596	2.6
Madrid	751,000	17,857	2.4
Seville	206,000	1,814	0.9
Valencia	251,000	3,262	1.3
SWEDEN:			
Goteborg	231,000	28,993	12.5
Malmo	116,000	14,893	12.8
Stockholm (excluding Bromma and Brännkyrka)	381,000	107,173	28.1
SWITZERLAND:			
Basel	138,000	14,512	10.5
Berne	108,000	12,222	11.3
Geneva	126,000	15,497	12.3
Zurich	207,000	26,524	12.8
UNITED STATES:**			
New York	5,896,000	1,415,108	24.0
Chicago	3,059,000	790,711	25.8
Los Angeles	1,150,000	280,754	24.4
Total of the 8 cities with over 1,000,000 population	17,419,000	3,840,327	22.0
San Francisco	695,000	215,464	31.0
Cincinnati	657,000	140,547	21.4
Milwaukee	605,000	120,924	20.0
Total of the 10 cities with 500,000–1,000,000 population	6,546,000	1,206,930	18.4
Washington	482,000	129,405	26.8
Minneapolis	457,000	115,833	25.3
Portland, Ore	341,000	84,432	24.8
Omaha	223,000	61,601	27.7
Total of the 30 cities with 200,000–500,000 population	8,675,000	1,701,905	19.6
Total of the 48 cities with over 200,000 population	32,640,000	6,749,162	20.7

* Partly estimated.

** There are shown, for purposes of comparison with cities in other countries, the total development of all cities in the United States in certain population groups and the development of certain representative cities within each of such groups.

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