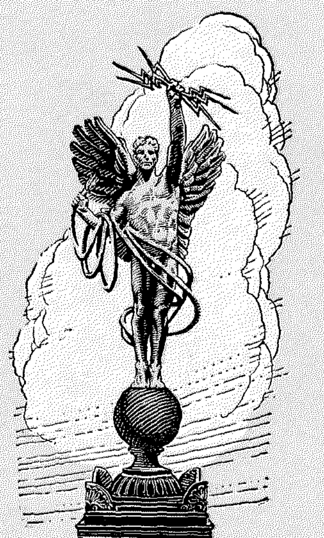
ELECTRICAL COMMUNICATION



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CONTENTS

Hans Christian Oersted at the Age of 26—From an Engraving by Chrétien, Paris, 1803

ODE BY HANS ANDERSEN

TIL H. C. OERSTED

Da Tanke-Lynet udsprang fra Din Pande,
En stoerre Seekraft Videnskaben fik,
En umaalt Skat Du gav til Verdens Lande,
Og gjennem alt det Skjoenne i det Sande,
Til Gud Du foerer os med aabent Blik.

TO H. C. OERSTED

When to thy mind there flashed the lightning thought,
The realm of Science, wondrous in the blaze,
Revealed such treasures in the Truth you taught,
That men before its Beauty bowed, and sought
A path to its Creator, by your ways.

R. A.

Pioneers of Electrical Communication

Hans Christian Oersted —VI

By ROLLO APPLEYARD

European Engineering Department, International Standard Electric Corporation

IN the history of electrical science, the first twenty years of the nineteenth century constitute the period of transition from static to current phenomena. Following upon the work of Galvani and Volta, discoveries throughout those two decades manifested themselves in all the advanced countries of Europe. In Denmark, however, at the end of that time, what had been the dream-phantasy of electrical communication suddenly took shape, inspired hope, gave confidence, and urged mankind to move towards reality; for in 1820, at Copenhagen, the secret now known as electromagnetism was wrested from nature by Hans Christian Oersted.

He was born in 1777 at Rudkjöbing, a small town on the island of Langeland, where his father was an impecunious apothecary. In 1778 a second son, Anders, completed the family for the time being, and when, in due course, the problem of education for the two boys presented itself, there were difficulties—schools in Rudkjöbing were scarce, teaching was crude, and the Danish language did not suffice for prospective needs and aspirations. The apothecary proved himself a man of resource. He enlisted the services of his friend Christian Oldenborg, a Teutonic barber and wig-maker of slender means, to teach the lads elementary German. The aid of the barber's wife was sought also to help them to learn to read and write. Arithmetic was at first an embarrassment, for the barber's knowledge in that direction was limited to addition and subtraction. Happily, a friendly schoolboy disposed of this trouble by imparting the rudiments of multiplication and division. From the baker they learnt a little drawing; from the burgomaster, a smattering of French; and from the local surveyor, some mathematics. Moreover, when Hans was twelve years of age, he assisted his father in the apothecary business, and thus acquired the beginnings of chemistry. A few years later, he gained increased access to books and developed an inclination towards literature. Notwithstanding privations, the two boys studied hard; their intelligence was above the average, and their parents endeavoured by every available means to assist them to materialise their aspirations. Hans and Anders were so successful that in 1794 they passed the students' examination and six months afterwards entered Copenhagen University. There they derived a little support from State funds, and made up the remainder by teaching. At that time, as physics and chemistry were not accepted by the University for a diploma, Hans directed his attention to pharmacy. In 1797 he passed in that subject with honours. He gave attention also to physics and astronomy. As his brother's ambition was to be a jurist, it was possible for them to study together certain subjects appertaining to both of their respective professions. They shared one lodging and, for a time, they shared one amusement—their scientific work. They shared expenses. They also shared one friend—the poet Oehlenschläger. The poet had one sister. She married Anders.

At the age of 20, H. C. Oersted showed definitely his bent towards literature and philosophy. So far did he improve his acquaintance with these subjects, that in 1797 he secured the University prize, a gold medal, for an essay "On the Limits of Poetry and Prose," and he won, in 1799, the prize for metaphysics.

His learning was becoming wide as well as deep. In his writings, early and late, may be discerned the influence of the German thinkers, Von Schelling (1775–1854, of Jena) and Kant (1724-1804, of Königsberg), whereby he was led to dwell upon the philosophy of nature, to treat facts in poetical fashion, and to perceive, in the study of physics, something of romance and of estheticism. Thus was he taught to distinguish between the individual and the material system that surrounds the individual, to separate matters of knowledge from matters of fact, sense from understanding and mind from things, to seek to combine and to marshal in thought the scattered elements of experience, and generally to approach towards transcendental theology. On obtaining his degree as Doctor, this influence was recognised in his thesis, the title of which was "The Architectonicks of Natural Metaphysics," and it was destined to play a significant part in his subsequent career. To the present age, such philosophy appears fantastic, but whatever may have been its merits or defects, the attempt to master it gave activity and scope to his imagination and induced him to perceive or to dream of identity between all manifestations of energy, such as light, heat, chemical action, electricity and magnetism.

The year 1800, memorable for the introduction of Volta's pile, discovered Oersted again doing service in an apothecary's shop, but not at Rodkjöbing. This establishment, which to-day still flourishes in Copenhagen, bears the name by which Oersted knew it—the Loeveapotheket (Lion Apothecaries). It was owned in 1800 by Professor Manthey, who happened to require the services of a pharmacist to whom he might entrust the business while he himself made a tour in Europe. Oersted, alive to the discoveries that had just been made by Volta, welcomed the opportunity this gave him for research. His first success related to the selection of solutions to produce the best results for the purposes of "galvanic electricity." He was impressed by the surprising results he was able to obtain by careful adjustment of the proportion of acid to water in the galvanic generator. He was also at work upon the classification of the earths and alkalis. In 1800, moreover, he took the Chair vacated by Manthey as Professor of Surgery. Reward for this labour came in the following year, when he gained at the University a money prize—the *stipendium cappelianum*—which supplied the means for him to travel for a few years at the expense of the State.

As soon as Manthey returned to Copenhagen, Oersted departed, in 1801, for Germany and France, filled with a desire to discuss pharmacy, metaphysics, and chemistry with men of light and leading. He found in Germany a realm of theory, in Paris a paradise of experimental philosophy. The tour enlarged his sphere of activity, brought him into touch with his peers, taught him the measure of himself, and indicated the lines of progress. The friendships that were to prove of greatest immediate significance, however, were that of Winterl and of Johann Wilhelm Ritter (1776–1810) who at that time was living at Weimar.

The quality of Oersted's literary powers was at this time illustrated by an episode that reflected credit alike upon his ability and upon his generosity. In the years 1802–1803 he was in Paris, and Ritter had just discovered the Ladungsaüle (secondary cell), consisting of a stack of plates of a single metal separated by discs of cloth or cardboard damped with an inert liquid, and charged by a voltaic pile. With it, Ritter produced sparks, decomposed water and salt solutions, collected oxygen, hydrogen and bases, and gave other remarkable evidences of its powers. Unfortunately, he could not speak, what he called, the "eigenthümlich-dunklen Sprache" of the French, but he desired to compete for the annual prize of the French Institut in natural science. Accordingly, he prevailed upon Oersted to prepare a translation from German into French. This Oersted did so well that Ritter declared he could himself understand the translation better than his own original German.

On his homeward way from Paris, in 1803, Oersted visited Brussels, Leiden, Haarlem and Amsterdam. At about that time, the University of Copenhagen was partly destroyed by fire, and the physical laboratory was burnt. The city fortunately contained a separate collection of physical apparatus, but it was held in private hands and Oersted could not at first secure free access to it. By judicious borrowing, however, he ultimately assembled what he required for a series of public lectures on electricity, magnetism, heat, light and combustion. His mind in these years was centred chiefly upon electro-chemistry, but he was still concerned with the identification of general laws, exemplified in all branches of natural philosophy. He was a keen observer, and gradually he developed into an enthusiastic experimenter. His experiments on tone-figures, carried out in 1806, proved to be of sufficient importance to lead to his appointment as extraordinary Professor of Physics at the University of Copenhagen. This increased the facilities at his disposal for further investigations. He became a teacher also at the Military School, and gave lectures to the general staff. In 1809 he produced a textbook of mechanical physics, which was republished in an enlarged edition in 1844.

In 1812–1813, Oersted made another tour in France and Germany. He remained a long time in Berlin, and published there, in German, his researches upon the identity of electric and chemical forces, which had already appeared in French in Paris. Upon his return to Copenhagen in 1814, he married, on May 17th, Inger Birgitte Ballum who was born on March 28, 1789, and who died on November 3, 1875. She was a daughter of N. R. Ballum, a pastor of Kjelby on the small island of Moer. At about the time of his marriage, he associated himself with a movement to introduce into chemical terminology the Gothic and German languages to displace the Greek and the French. In addition, he sought to raise science to the status of religious culture. He usually worked with his classes, in lectures and otherwise, for five hours every day, and it was his custom to give each month a special lecture to explain new advances in science.

Then came the year 1820, the year of his great discovery, the happiest year of his life. By what has been described as one of those

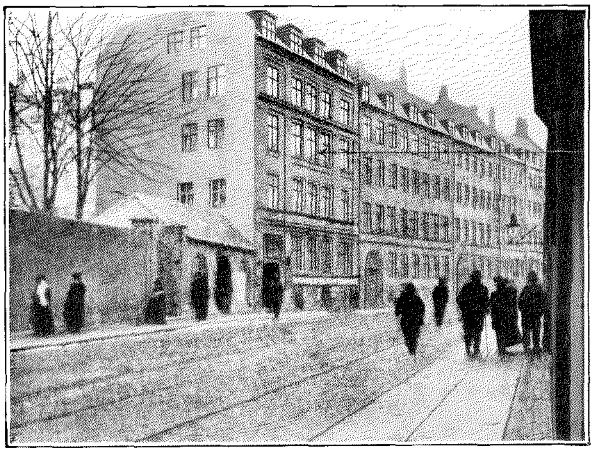


Figure 1—Oersted's House in Noerregade, Copenhagen. The original photograph was taken in 1907, shortly before the building was demolished to make way for Telephone House. The arrow indicates the room in which the first experiment on electromagnetism was performed.

lucky throws that come not twice in a thousand years to mortals, he found that an electric current can deflect a compass-needle. He reasoned that just as an electric current can produce heat and light, so it might exert magnetic influence. He had for some years possessed the germ of this idea. He convinced himself that every voltaic circuit has a magnetic field, and that the

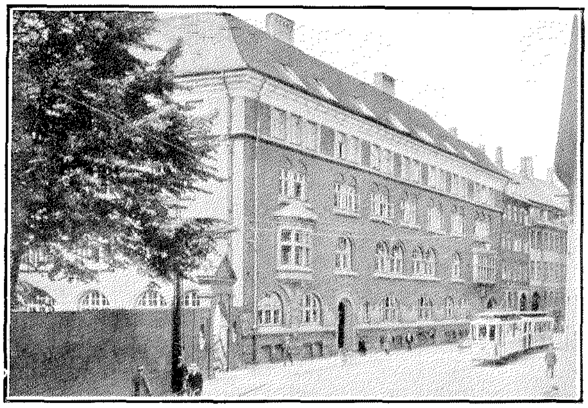


Figure 2—Telephone House, Copenhagen—The Headquarters of the Copenhagen Telephone Company.

direction of movement of a magnetic needle placed near such a circuit is determined by that field. An account of his investigations, in Latin, was distributed by him to Societies and Academies in all the capitals of Europe. Praise and honours came in upon him from all sides. From the Royal Society of London he received the Copley Medal, and from the Institut of France a prize of 3000 francs.

The exact date of Oersted's discovery of electromagnetism is unknown. Arago (*Oeuvres* Vol. 2, p. 50) assigns it to 1819, but it may have been in the early Spring of 1820. The announcement was dated from Copenhagen, July 21, 1820, and time must have been necessary to prepare that account. The place where the discovery was made has been carefully ascertained.

In 1819 Oersted had moved to a house, Noerregade 34 (Figure 1), belonging to the cabinet maker, Pingel. There for five years he remained. The house, which has since been demolished, was located at what is now the southern end of Telephone House (Figure 2). It resembled a previous house there that, in common with all others in the street, was destroyed in the bombardment of 1807. Oersted rented, on account of the University, seven rooms on the third floor front and four rooms at the back for £77 a year. His private dwelling was

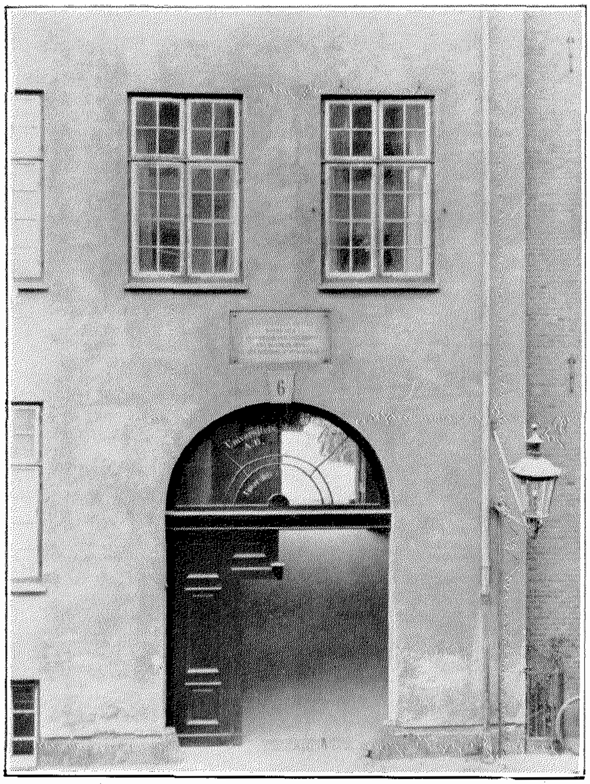


Figure 3—Entrance to Studienstraede 6, an Annex of Copenhagen University. The memorial plate above the doorway records that H. C. Oersted lived there as a Professor from October, 1824, until his death on March 9, 1851.

on the second floor. The two rooms facing Noerregade formed the lecture-room, the scene of the discovery; the others were preparation rooms. It has been possible to locate approximately the point in space, in Telephone House, where the original experiment was performed.

In 1824, Oersted departed from Noerregade, 34, and occupied a Professor's house (Figure 3), belonging to the University, at Studienstraede 6. In 1829, he founded the Polytechnic School and allowed some of the rooms of his own house to be used by that institution. At that time there was a courtyard separating his house from a private building, afterwards requisitioned by the University (Figure 4). In 1890, for the centralisation of studies in Physico-Chemistry, Inorganic Chemistry, and certain branches of Mathematics, all the polytechnic schools were transferred to a new building in Soelvgade.

On the day of his discovery, when he had assembled the apparatus, a lecture prevented him from trying what he had in mind. At the close of the lecture, he asked his class whether they would like to observe what might happen. The class remained and witnessed the result—a deflection of the compass-needle (Figure 5), when there was an electric current in a neighbouring wire, placed in proper relation to the needle. The movement was so small that Oersted was inclined at first to attribute it to capricious disturbances. Moreover, he was perplexed because he could not account for the fact that the movement of the poles of the pivoted magnet, in a horizontal plane, was at right angles to the direction of the current in the wire. Why was not the line of action of the magnetism the same as that of the originating electric current? Later, he returned to the investigation; he now used a much larger battery—copper-zinc, sulphuric acid—and he obtained a decided deflection of the needle. His procedure was thus in accordance with the most

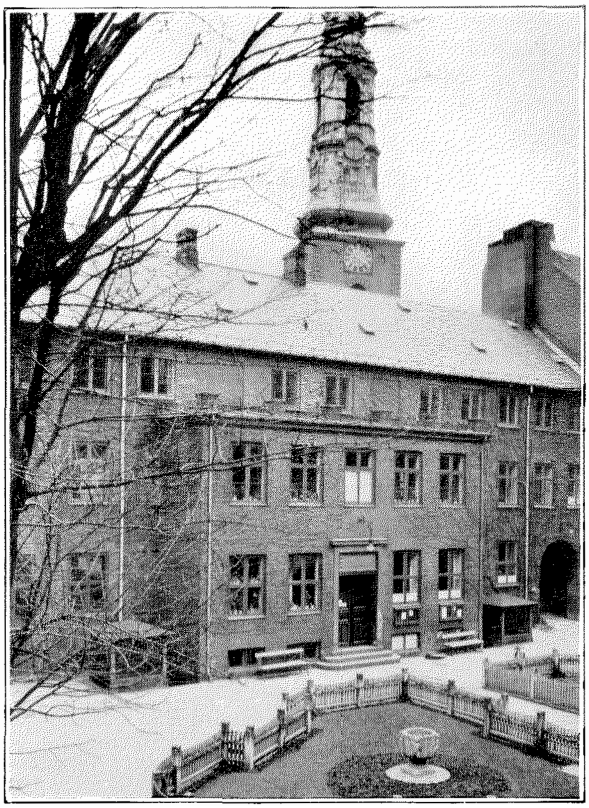


Figure 4—Royal Technical College, Founded by H. C. Oersted in 1829. Here he lectured. It is now an annex to Copenhagen University. In the background is the tower of the Church of St. Petrie. There is a legend that to this tower Oersted extended wires from his house opposite, and installed the first electromagnetic telegraph signaling device in Denmark.

cherished methods and traditions of the pioneers: to his imagination he gave scope enough to inspire him with a definite object of research, by experiment he sought in the direction of that object for new facts and, lastly, when a clue appeared, he extended the research in each direction, towards weakness and towards strength, far beyond the limits required for a class demonstration of the phenomena.

In other investigations he studied especially the constitution and properties of water, and he developed for this research a new instrument (Figure 6) for measuring the compression of liquids. Later he examined the pressure-volume law for air, and other substances, and he carried the pressure to the limits of the apparatus then existing. Further, he investigated the derivation of aluminium from clay, and a new method of preparing oxides of chlorine.

A third State-aided tour, in 1822–1823, took him to England, France and Germany. On that occasion he had an opportunity to observe especially the progress of investigations with regard to light, and he replenished the laboratory at Copenhagen with a number of instruments. On his homeward journey he established the

Figure 5—The Compass Used in H. C. Oersted's Original Experiment on Electromagnetism. The wooden support was added later. The instrument is now in the Museum of the Physical Laboratory of Copenhagen Polytechnic Institute.

"Society for the Distribution of Teaching Natural Science." In 1828 he visited Norway and Berlin where he addressed the physicists; and in 1830 he made a similar visit to Hamburg.

He next appears in 1834, discussing questions of physics at Göttingen with Gauss, whom he had met at Altona in 1827. From him he heard of the latest observations in magnetism, and of

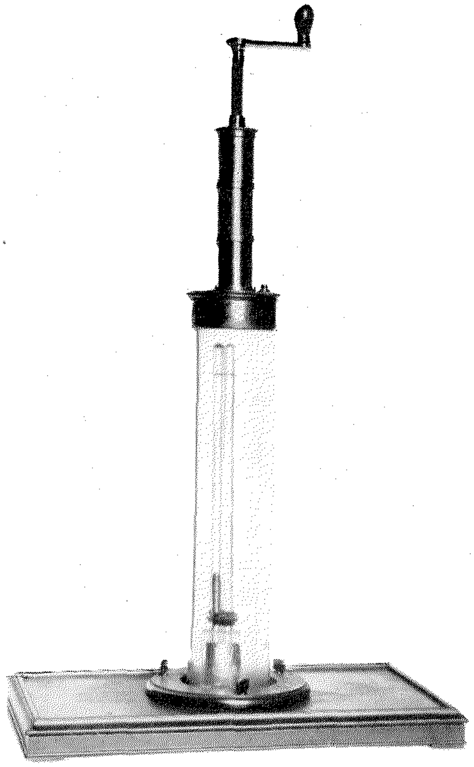


Figure 6—H. C. Oersted's Piezometer, Now in the Museum of the Physical Laboratory of Copenhagen Polytechnic Institute. The barometer tubes inverted in mercury are seen within a glass cylinder having thick walls. The whole was filled with water or other liquid, and the pressure was applied by the piston, operated by a screw rotated by the handle.

the new methods of measurement that Gauss had introduced. This concerned Oersted, for he had in mind the establishment of a magnetic observatory at Copenhagen. A few years later, he again went to Scand navia, where he discoursed upon subjects in a plane beyond the conventional circle of natural philosophy—he lectured upon the relation of physics to beauty, somewhat in accordance with Leibnitz's hypothesis of harmony and unity between the laws of nature and the laws of reason.

His study of Danish literature never ceased. Into political affairs he entered boldly, and he made frequent communications to newspapers and journals, pleading for freedom of the press and for the advance of generous ideas in government. At the other extreme, he went so far as to write in 1836 a great lyric-didactic poem entitled, "The Air Ship." It will suffice here to quote briefly from L. and J. B. Horner's English translation:

"Turn, then, and look
Upon the varied business of man's being,
Where the inventive spirit finds fit work
For the free hands to do. In sooth, we might
A thousand wonders add unto the seven
Which the past world astonished.
. . . .
What Nature lent
Her feathered children of the air—to soar
With outspread wing, free in Heaven's azure vault—
Art has outdone; and now majestic floats
The dweller of the earth in regions where
The kingly eagle has not dared to soar.
Did not the hapless fate of Icarus
The poet warn, that such an airy flight
Secure he cannot dare? Praised be the age
When wonders are so rife, that one like this
Is lost among their number manifold."

Oersted, however, was not the first to derive poetic inspiration from the advance that was being made in aeronautics. The subject had long engaged the attention and had fired the imagination of men in the front rank of natural science. Twenty years earlier, Sir George Cayley had contributed a valuable article to the *Philosophical Magazine* (Vol. 47, No. 214, February 1816) on aeronautics, and had concluded with a verse, at once stirring and prophetic, by Dr. Darwin:

"Soon shall thine arm, unconquer'd steam afar
Drag the slow barge or drive the rapid car;
Or on wide waving wings expanded bear
The flying chariot through the fields of air.
Fair crews triumphant, leaning from above,
Shall wave their fluttering kerchiefs as they move;
Or warrior bands alarm the gaping crowd,
And armies shrink beneath the shadowy cloud."

Behold Oersted now, Secretary of the Königl. Gesellschaft der Wissenschaften; Professor Ordinarius at Copenhagen; Corresponding Member of the Science Academie of the French Institut; Director of the Polytechnic School of Copenhagen, which through his personal influence with Friedrich VI he personally had called into existence; Knight of the Ehrenlegion (1837); Conferenzrat (1840); Knight of the Prussian Order *pour le mérite* in the Sciences and Arts (1842); possessor of the honorary diploma of Erlangen as Doctor of Medicine (1842), and of the Grand Cross of Dannebrog (1847). These dignities, however, did not prevent him from extending his studies, his sympathies, and his beneficent influence.

To appreciate the scope and character of the man and his achievements, it is necessary to recall the turbulent age and circumstances in which he lived. His boyhood was marked by the war of 1789, between Denmark and Sweden, by the struggle against serfdom in his country, and by a general movement towards political freedom. In the subsequent wars, Denmark—threatened by Napoleon—entered a league that brought her into conflict with England. In 1805, Napoleon overthrew Austria and Russia at Austerlitz, and formed the Confederation of the Rhine under the protection of France. This was followed in 1806 by the abdication of the Emperor Francis II, an event that marked the end of the Holy Roman Empire. The ultimate result was that when, in 1814, the Napoleonic Empire began to fall to pieces, Denmark lost possession of Norway, and suffered impoverishment and distress, followed by an interval of agitation for a free constitution—an agitation that in various phases disturbed the country to the day of Oersted's death.

To comprehend where Oersted stands in the world's history, therefore, it is essential to realise the perilous position of his country at several periods during his long life. The main trouble began in 1780, when Denmark declared the Baltic to be closed to the armed vessels of belligerent Powers. At that time England was at war with the American Colonies, and also with France and with Spain. Holland, Denmark, and the whole Baltic sought nevertheless to trade with England's enemies, in timber, tar, hemp, cordage and provisions. England accordingly used armed vessels to search merchantmen. The Dutch held that a neutral flag should exempt from seizure. England replied by attacking the Dutch. Russia assisted merchantmen bound for French ports. Sweden and Denmark formed an alliance to protect their trade. Denmark meanwhile kept in close touch with Russia and, on December 7, 1800, Bonaparte joined the Russian league and devised a plan to invade India. His first move in this direction, however, was towards the commercial exclusion of English commerce from the continent of Europe. England hit back by placing an embargo on Russian, Danish, and Swedish ships in British ports, and at the same time she fitted out a fleet for the Baltic.

Denmark supported by France, followed by placing an embargo on all British ships in her ports; she entered Hamburg and closed the Elbe to the English, she took possession of Lübeck and, aided by Prussian troops, the combined forces closed the Weser and the Ems to English vessels.

In the early Spring, England restored the balance by sending her fleet through the Sound, and by attacking Copenhagen. This fleet was under the command of Sir Hyde Parker, with Vice-Admiral Nelson as second in command. Parker did not excel, but Nelson, with his accustomed skill and zeal, accomplished the task. Parker held himself in reserve with many of his ships and, thinking that Nelson would suffer a reverse, made the signal, "Discontinue the action." It was then that the famous incident occurred in which Nelson turned his blind eye to the telescope and hoisted his own battle signal, "Engage more closely." Copenhagen collapsed; Russia also gave in to England, but France did not.

The next event that closely concerned Oersted was in 1807. Bonaparte insisted that Denmark, Sweden and Portugal should be compelled by France and Russia to enter into war against England. His object was to add the navies of Denmark, Sweden and Portugal—about forty ships of the line—to his forces. For England, it was a matter of life or death, and her immediate counter blow was to seize the Danish fleet. Admiral Gambia sailed from England on July 26, 1807, with forty-two fighting ships, and also with twenty-seven thousand troops under Lord Cathcart. Zealand was blockaded, Copenhagen was bombarded from September 2d until September 5th of that year, and the entire Danish fleet of eighteen sail of the line, ten frigates, and forty-two smaller vessels were forced to surrender.

A great misfortune fell upon H. C. Oersted in 1813 when his brother, Niels Randulph Oersted, who was an officer in the Russian army, was killed at the battle of Leipsic. The troubles of his country pursued the great philosopher to the end, for in 1848 Germany was seeking to annex part of Denmark, and the Danish army absorbed much-needed wealth. It is noteworthy that in France, in 1848, Arago was Ministre de la Guerre et de la Marine, and that Oersted, counting upon their friendship in the field of science, tried through him to influence French opinion concerning Slesvig in favour of Denmark, but without success.

It is necessary next to glance at the state of electrical knowledge as Oersted found it, and as he left it. That lightning, from a distance, could reverse the poles of a magnet, and that an electric discharge from a Leyden jar would have the same effect, was familiar to him. Benjamin Franklin, in 1749, had used these facts as an argument in proof of the identity of lightning and electricity; and "the magneticalness of lightning" had been referred to in 1756, in a history of the Royal Society. Similarly, that there was possibly an analogy between electricity and magnetism had long been a suggestion amongst physicists; for in 1767, Jan Hendrik Van Swinden, of Amsterdam, had discussed it in a prize essay and had decided that there is no definite analogy. There must be recalled also the circumstance that, in 1802, Adam Walker published "A System of Familiar Philosophy" relating to the identity of light, heat and electricity, as modifications of a single agency, and that he declared that, "we have infinite data in favour of an electromagnetic fluid."

Hence, it is not surprising that Oersted's discovery was, at first, imperfectly understood, and that there were critics who suggested that it had been anticipated. Earlier, he had himself vainly endeavoured with Ritter to trace an action between electricity and magnetism. Particulars of this investigation are to be found in the correspondence between the two physicists. To establish the priority of Oersted, it remains only to clear the issue in respect to results obtained by the Italian lawyer and mathematician Romagnosi. The case in favour of Oersted, in this instance, was established definitely by his countrymen, Absalon Larsen, K. Prytz and M. C. Harding. To elucidate the matter, it was desirable to dispose of the accounts of Romagnosi's results as given by Professor Giovanni Aldini in his *Essai*, published in 1804. At page 339 of the *Essai*, after describing certain developments in galvanism, Aldini directs attention, as follows, to an experiment which he ascribes to the Genoese chemist Giuseppe Mojon:

"Ayant placé horizontalement des aiguilles à coudres, très fines, et de la longuer de deux pouces, il en a mis les deux extrémités en communication avec les deux pôles d'un appareil à tasses de cent verres: au bout de vingt jours il a retiré les aiguilles un peu oxidées, mais en même temps magnétiques, avec une pôlarité très sensible. Cette nouvelle propriété du galvanisme a été constatée par d'autres observateurs, et dernièrement par M. Romanesi, physicien de Trente qui a reconnu que le galvanisme faisait décliner l'aiguille aimantée."

(Having placed horizontally, some very fine sewing needles, two inches in length, he put the two ends in communication with the two poles of a battery of 100 cells: at the end of twenty days, he removed the needles slightly oxidised, but at the same time magnetic, with a very perceptible polarity. This new property of galvanism has been established by other observers, and lastly by M. Romagnosi, a physicist of Trente, who has noticed that the galvanism causes the magnetised needle to decline.)

What then was the experiment carried out by Romagnosi?

The *Manuel du Galvanisme*, by Joseph Izarne, published in Paris in 1805, contains a description of the various forms of galvanic apparatus employed up to that time for researches in physics, chemistry and medicine. As Izarne was Professor of Physics at the Lycée Bonaparte and as he was associated with the learned societies concerned with galvanic research, his testimony may be accepted as representing enlightened contemporary knowledge of the subject. At page 120 he deals with magnetic effects of electrification, and he describes:

"APPAREIL POUR RECONNAITRE L'ACTION DU GALVANISME, SUR LA POLARITÉ D'UNE AIGUILLE AIMANTÉE

"*Préparation.* Disposez les tiges horisontales *a b*, *b d*, de l'appareil . . . de manière que les deux boutons se trouvent à une distance un peu moindre que la longueur des aiguilles que vous voudrez soumettre à l'expérience; et, à la place des boutons *bb*, qui sont vissés sur leur tige respective, adaptez aux tiges, ou une petite pince, ou bien un petit ajutage applati.

"*Usage.* Après avoir placé l'aiguille, de manière que ses deux extrémités soient prises dans les deux petites pinces, établissez une communication de d, avec une des extrémitiés d'un Electromoteur (Volta pile, *vide* p. 19), et de a, avec l'extrémité opposee.

"*Effets.* D'après les observations de Romagnési, physicien de Trente, l'aiguille déja aimentée, et que l'on soumet ainsi au courant galvanique, éprouve une declinaison; et, d'après celles de J. Mojon, savant chimiste de Gènes, les aiguilles non-aimentées acquièrent, par ce moyen, une sorte de polarité magnétique."

(APPARATUS TO SHOW THE EFFECT OF GALVANISM ON THE POLARITY OF A MAGNETIC NEEDLE

Preparation. Arrange the horizontal rods *ab*, *bd*, of the apparatus (Figure 7) in such a manner that the two knobs are at a distance apart a little less than the length of the needles with which it is desired to experiment; and at the knobs *bb* that are screwed to their respective rods, attach a small clip or a small flattened extension.

Manipulation. After having placed the needle in such a manner that its two ends are held in the two small clips, establish connection from *d* with one of the terminals of the Volta pile, and from *a* with the opposite terminal.

Effects. According to the observations of Romagnosi, a physicist of Trente, a needle already magnetised and subjected thus to a galvanic current will show a declination; and according to those of J. Mojon, a learned chemist of Genoa, non-magnetised needles acquire by this means a sort of magnetic polarity.)

Here, there is nothing in common with Oersted's experiment; for here the needles are fixed and in Oersted's case the compass needle is free to turn; here the current is passed through the needles and in Oersted's case it traverses a separate conductor.

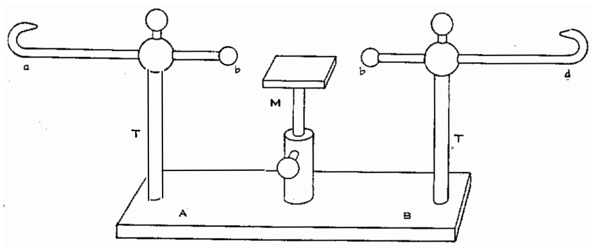


Figure 7—Apparatus as Used by Romagnosi.

The original account of Romagnosi's experiment appeared in a newspaper, the *Gazetta di Trento*, of August 3, 1802, and it leaves no doubt of the manner in which he carried out the experiment. Figure 7 illustrates the support upon which the needles were placed and held fixed by clips, and the knobs by means of which the current was passed through them. The *Gazetta* account is as follows:

"Senator Giandomenico Romagnosi, a resident of this city and known to the literary world through his other profound works, hastens to communicate to the physicists of Europe an experiment relating to the galvanic fluid as applied to magnetism.

"Having prepared the pile of Mr. Volta, composed of round discs of copper and zinc alternating with an interposed layer of flannel moistened with water impregnated with a solution of sal ammoniac, he attached to the pile a silver wire linked at various intervals like a chain. The extreme link of the chain passed through a glass tube, from the outer end of which a silver button projected, it being connected to the said chain.

"This being done, he took an ordinary magnetised needle shaped like a mariner's compass mounted at the centre of a square wooden block, and after having removed its crystal cover he placed it on top of a glass insulator in the vicinity of the said pile.

"Then he took hold of the silver chain, and seizing the same by the said glass tube, he applied its end or button to the magnetic needle, and by holding it in contact for a period of a few seconds, he caused the needle to diverge some degrees from the polar direction. After the silver chain had been removed, the needle remained stationary in the diverging direction now given it. Once more he applied the same chain making the said needle diverge still more from the polar direction, and he always obtained the result that the needle remained in the position where he had left it, in such a manner that the polarity remained entirely annihilated. In order further to verify this result, he brought as near as possible to the magnetised needle (without touching it, however), now a piece of watch spring and then other iron instruments, which previously attracted the same needle forcefully at a four times greater distance, but now when exposed to the action of galvanism they were unable to move the needle even the width of a hair.

"Now look how Mr. Romagnosi then proceeded to restore the polarity. With both hands he tightly gripped, between the thumb and the index finger, the extremity of the wooden insulated box without shaking it, and he held it thus for some seconds. Then the magnetised needle was seen to move slowly, and to recover its polarity, not all at once, but by successive pulsations in similar manner as a clock-hand serving to indicate seconds.

"This experiment was made in the middle of May, and was repeated in the presence of some spectators. On such occasions he obtained also, without difficulty, the electric attraction at a quite appreciable distance. He made use of a fine piece of thread soaked in water saturated with sal ammoniac, and attached it to a small glass rod, and then he approached the said silver chain to the thread, to within a distance of about one line, and he saw the thread fly into contact with the button of the chain and swing up, it remaining all the time attached in a manner similar to the electric experiments."

From this evidence it is manifest that Romagnosi was concerned solely with the effect of electrical discharges through the magnets themselves, and that he repeated, in effect, the experiment of Mojon, by sending a more or less continuous current through the magnets. As his magnets were fixed, he did not observe the rotary movement that was the essence of Oersted's discovery. Moreover, Romagnosi himself made no claim to such a discovery. Romagnosi observed the more or less permanent magnetising or demagnetising effect of a current through the magnets—the annihilation of polarity. Oersted did not send a current through magnets, but through a separate conductor. Consequently the novelty of Oersted's experiment may now be regarded as established beyond controversy.

The Copenhagen experiment gave to research an impulse as far-reaching as it was momentous. The account of it arrived in Paris from Switzerland, and at the meeting of the *Académie* on September 11, 1820, an academician who had just arrived from Geneva repeated it with great success. Seven days later, on September 18th, Ampère made known his grand generalisation concerning it. On September 25th, Arago described, at the Bureau des Longitudes, experiments in which a current from a voltaic pile, when conveyed through a conductor, is caused to magnetise rods of soft iron separate from the conductor. On November 16th, at a meeting of the Royal Society, Sir Humphry Davy read a paper on the magnetising influence of galvanism on bars of steel (*Philosophical Magazine*, Vol. 56, 1820, pp. 381–382). The experiments were made in the laboratory of the Royal Institution. The batteries were twelve troughs of four-inch plates, mounted with double coppers "agreeable to Dr. Wollaston's plan." In the same journal, at page 394, is an account of a further result, attributed to Oersted, and explained as follows:

"A plate of zinc (about three inches high and four inches broad) placed in, and by an arch of small wire connected with a trough nearly fitting it, made of thin copper and containing a mixture of one part of sulphuric acid, one part of nitric acid, and 60 parts of water, forms an apparatus, which being suspended by a very small wire (only sufficiently strong to bear its weight), will, if a powerful magnet be presented to it, exhibit magnetic polarity —turning its corresponding pole to the pole of the magnet. The suspending wire is attached to the apparatus by a thread rising from one side of the trough to the wire, and descending to the other side of the trough; and the plate of zinc is kept from coming in contact with the copper case, by a piece of cork interposed on each side of the plate."

The *Philosophical Magazine*, Vol. 57, 1821, pp. 40–49, contains a paper by Hatchett on the electromagnetic experiments of Oersted and Ampère, in which Oersted is said to have opened up a new field to the inquiries of philosophers, for—

> "It is to him that we owe that fine observation, that a metallic wire, which communicates with the two extremities of a Voltaic electrical apparatus, acquires the very remarkable property of acting at a distance on a magnetic needle. This metallic wire has been named the conjunctive wire."

Hatchett states that it had for some time been known that conjunctive wires may become heated, redden, and burn in atmospheric air, and he emphasises the fact that—

> "For twenty-three years the electric piles of Volta had been in use, and no philosopher had yet thought of bringing a magnetic needle near one of these piles in action. This inspiration was reserved to Oersted; and it must be confessed, that chance had much less share in it than in many discoveries with which physical science has been enriched."

Oersted had long before written a memoir with the title, "An Inquiry into the Identity of Chemical and Electrical Forces," and this book was translated and published in 1807. In that inquiry, he sought for proofs that magnetic and electric forces are identical, but he found none. Hatchett remarks upon the curious circumstance that when Oersted discovered the action of the conjunctive wire upon the needle, he explained this new phenomenon by a hypothesis which supposes that the negative electricity acts only on the northern pole of the needle, and that the positive electricity acts only on the southern —*Annales de Chemie*, August 1820, p. 244— implying a total difference between electric and magnetic fluids, since the magnetic fluid, whether considered as positive or negative, ought to act equally on both poles.

To demonstrate, by experiment, the identity in question, it was necessary to explain all the phenomena—the mutual action of two magnets, the action of a conjunctive wire upon a needle—"without admitting in a magnet any other fluid than the acting electric fluid." This task was undertaken by Ampère. The inter-relationship of electricity and magnetism was further established by Arago who observed that steel needles, placed within spirals of wire, became magnetised when electric discharges were passed through the wire from static electrical machines, or when currents were passed through them from Voltaic batteries.

In the discovery of aluminium, Oersted played a great part, but to Wöhler he had to leave the honour of producing the metal in a pure state. Wöhler, however, recognised the value of Oersted's work in this direction.

Oersted's view was that, given diligence and a healthy brain, advances in natural science can be made even by those of but limited education. It was in accordance with principles of this character that he proposed, in 1824, and founded in 1829, the Selskabet for Naturlaerens Udbredelse—the Society for the popularisation of Natural Science. This he did by giving lectures in the towns, by the distribution of pamphlets, and by supporting those who desired to improve their acquaintance with technical science. The Society still flourishes, and in memory of its founder it has established an Oersted medal as a prize. He realised that the inculcation of scientific principles governing the operations upon which men and women are employed, is a better mission for such a Society than the attempt in schools to teach manual work. He was not an advanced mathematician, but he recognised the necessity for having close enough acquaintance with the subject to enable the results of investigations to be reduced to numerical terms. His dominating idea was the inter-relation between what at that time were called the various forces of the universe; and he saw that the future welfare of his country must depend upon the development of inventive faculties, directed towards the utilisation of natural resources. His plea, therefore, was for technical education strongly supported by natural science. In his wanderings over a wide field, he was led at last by his philosophy into close touch with the basic problems of humanity. Thus he learnt to see life steadily, as well as sympathetically and to see it whole. His influence upon contemporary thought and action finds testimony in Hans Christian Andersen, who confessed to the support and encouragement he received from him.

In 1846, Oersted again visited England, and he was present at the meeting of the British Association at Southampton in that year. The remarks, on that occasion, of Sir John Herschel convey an idea of the impression created upon Englishmen by Oersted, and by his discoveries:

"To look at his calm manner, who could think that he wielded such an intense power, capable of altering the whole status of science, and almost convulsing the knowledge of the world . . . (his discoveries) went almost to the extent of obliging them to alter their views on the most ordinary laws of force and motion. . . . The electric telegraph, and other wonders of modern science, were but mere effervescences from the surface of this recondite discovery, which Oersted liberated, and which was yet to burst with all its mighty force upon the world."

The fiftieth anniversary of his association with Copenhagen University was on November 7, 1850. At that festival he was greeted by all Denmark, from the King to the most lowly of the people. The Danish Government presented him with a country residence, Fasangaarden in Frederiksberg Park, precious to his memory as the former home of his friend Oehlenschläger. Students in torch-light procession sang verses composed in his honour, and men and women of all ranks and opinions joined with one accord in the festivities. He was then seventy-three years of age, and was actively occupied with lectures and with literature.

During that winter, he busied himself with preparations for the transfer to Fasangaarden, but he never occupied it. He caught cold, and, after a brief illness, died on March 9, 1851.

He was below medium height, of open countenance, of florid complexion, somewhat stout, in manners kindly, by nature gracious, loyal to his King, devoted to his country and to the cause of humanity. In his scientific work he was often baffled but never discouraged, his perseverance helped him to the end. Towards the end, he was able to write to a friend the secret of his life:

"In my family I am as happy as a man can be. I have a wife whom I love, and children who are dear to me and who prosper. I have three sons—of whom one is of age and is employed in the forestry service of the King—and four daughters, of whom the eldest three are either married or betrothed. My brother, who for some time was a Commissioner for the King in our provincial parliament, has recently become a Minister of State. As for me, I am still a professor and director of the Polytechnic School and Secretary of the Royal Society of Sciences."

Oersted thus had three sons and four daughters. The eldest daughter, Karen, married E. A. Sharling, Professor of Chemistry at Copenhagen. Another daughter, Marie, married S. N. P. Hasle, who for forty-one years was pastor at Odsherred in Zeeland. The youngest, Matilda, remained to cherish her father's old friend Hans Christian Andersen, and to her Andersen bequeathed the manuscripts of his own stories. Oersted's sister, Barbara Albertine, married Georg Jacob Bull, who became President of the Supreme Court of Norway.

His dearest friend, Adam Gottlieb Oehlenschläger (1779–1850) also joined the immortals; with his poems and his sagas he became the great minstrel of the North, who sustained his countrymen with hope and courage in the midst of their tribulations.

In 1920, the Foundation Carlsberg published, under the editorship of Mr. M. C. Harding of the Polyteknisk Laereanstalt, Copenhagen, a collection of Danish, French, German, and a few English letters, representing some of the correspondence of H. C. Oersted with men of science of his time. Mr. Harding has dealt with these documents with such care and precision that they now constitute the best possible means both of judging of the scope and character of Oersted's opinions, friendships, qualities, and achievements, and of observing the variety of ways in which his influence was exerted. From them it appears that, at the threshold of his professional life, Oersted was regarded by some of his scientific acquaintances as *un exalté*, and too empirical, and as something of a dreamer. In 1820, however, when one of his dreams came true, most of his friends—and even the exacting Bezelius—were quick to acknowledge the substantial character of the stuff of which the dreams were made. Erman recognised the discovery of electromagnetism at once at its true worth. Seebeck, on the first verbal account of it, shook his head, but when he read the complete communication he offered "a thousand warmest greetings," and said it deserved a prize like that given by Bonaparte to Volta. Arago, who probably had been acquainted with Oersted for a few years before the announcement of the great experiment, also at first entertained doubts, but became convinced and was the first person in France to direct the attention of scientific men to it. To Switzerland, and to De la Rive, however, belong the credit of the first public demonstration. In England, on November 16, 1820, at the Royal Society, Davy assigned to Oersted the honour of priority in the discovery of electromagnetism, and declared that no anterior experiments by others could change the fact of that priority. His opinion of Oersted is also recorded—"He is chiefly distinguished by his discovery of electromagnetism. He is a man of simple manners, of no pretentions, and not of extensive resources; but ingenious, and a little of a German metaphysician." Faraday for once confessed that chance counted for something; but he was convinced of the originality of Oersted's experiment. He said of Oersted: "His constancy in the pursuit of his subject, both by reasoning and experiment, was well rewarded in the winter of 1819 by the discovery of a fact of which not a single person beside himself (Oersted) had the slightest suspicion, but which, when once known, instantly drew the attention of all who were able to appreciate its importance and value."

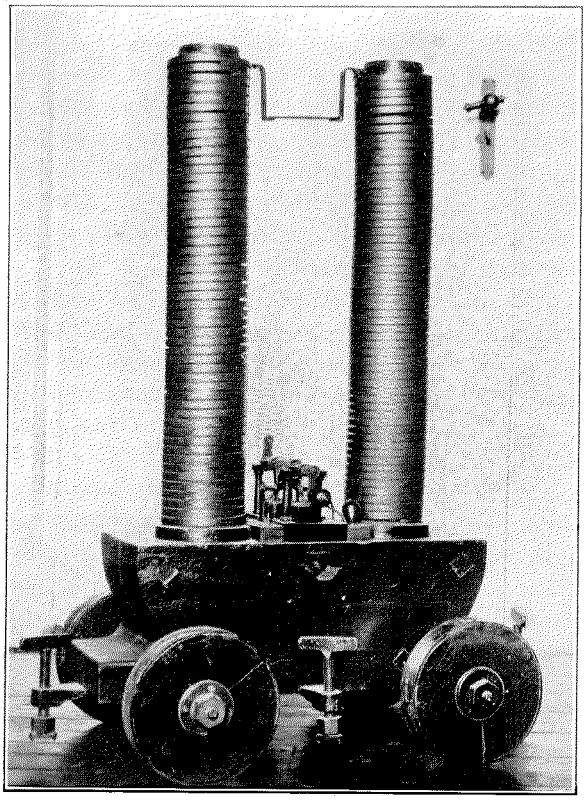


Figure 8—H. C. Oersted's Electromagnet, Constructed After He Had Seen Faraday's Electromagnet. The height of the magnet cores was about 50 centimetres.

Oersted and Faraday met for the first time in London in 1823. Owing to the subordinate position of Faraday to Davy, Oersted could not then get into direct touch with him. It was therefore under conduct of Davy that Oersted took part in some experiments of Faraday, that year, at the Royal Institution. In 1846, when Oersted for the second time visited Faraday's laboratory, his attention was given to the great horse-shoe electromagnet. At that time Faraday was not present, but his old laboratory assistant acted as guide. After the 1846 British Association Meeting, however, Faraday himself showed Oersted his experiments on diamagnetism. Upon his return to Copenhagen, Oersted constructed an electromagnet (Figure 8) which is still preserved in the Polytechnic School. With it, in 1847, he demonstrated Faraday's experiment in diamagnetism at the Royal Académie of Copenhagen, and he continued that work until 1849. The two philosophers followed closely the accounts of one another's researches on such subjects as compressibility, the validity of Mariotte's law, the liquefaction of gases, and the formation of sonorous figures on vibrating plates.

Of all the congratulations he received from men of scientific perception, the most emphatic were those of Dr. Thomas Young who spoke of the marvellous discovery that elevated Denmark to a rank in science which it had not held since the days of Tycho Brahe. In Germany, the learned Dr. J. S. C. Schweigger paid no less a tribute when he declared that Oersted's experiments in magnetism were the most interesting that had been carried out in that domain of science for a thousand years. Concerning telegraphy Schweigger, in 1848 wrote to Oersted:

"Sir waren es, mein verehrter Freund, dessen Elektromagnetismus die engste Verbindung der Menschen herbeigeführt durch die nun so Zahlreich angelegten electromagnetischen Telegraphen. Statt sich dieser engen Verbindung zu freuen, fangt man Kriege an und entzweit selbst die durch Abstammung, Sprache und Sitte von Natur befreundeten Völker, wie Dänen und Deutsche."

(It was you, my honoured friend, whose electromagnetism made the close bond between men, by means of the now numerous forms of electromagnetic telegraphy. But instead of this bond being a cause for rejoicing, it has begun to be a means of war and separation of languages and customs of friendly peoples like the Danes and the Germans.)

The first in America to emphasize the importance of Oersted's discovery of electromagnetism was Joseph Henry (Transactions of the Albany Institute, Vol. 1, pp. 22–24, 1830). By 1841 the name of Oersted was as well known in America as in any part of Europe.

The impression created by the researches of Oersted is that his greatest successes were derived from experiment. Even in 1801 he was seeking to improve his powers as an experimenter by learning glass-blowing in Leipsic, and a year or two afterwards he was at Haarlem repeating Ritter's experiments in company with Van Marum. In 1846 he observed with enthusiasm the experiments of Faraday. It is curious to observe, therefore, that in 1849, when he was approaching the last stage of his career, he confessed, in a letter to Sir John F. W. Herschel, that he had continuously turned his mind against the results which could be drawn from the experimental sciences to those which are commonly treated as depending particularly upon mental powers. He added: "I am far from approving the German metaphysics. . . . I have long since been led to form a philosophy of my own . . . through the corporal world to the mental." The truth is that like all who seek earnestly to penetrate the laws of nature, he developed a mind inherently unstable but maintained in equilibrium by perpetual spin and oscillation between fact and opinion, experiment and enlightened imagination, the never and forever of all time.

It is in his friendship for Ritter that his finest qualities appear. He met him first in 1801 when Ritter's work was little known. In March, 1803, in Paris, Oersted gave a demonstration of Ritter's invisible (ultra-violet) rays that could act chemically, and in May of that year he did the like for Ritter's secondary cell. Biot thereupon asked Oersted to obtain from Ritter a direct communication upon these subjects, and it was because of it that Ritter, obscure, reserved, eccentric, and impoverished, obtained the prize of 3000 livres. Ritter in 1802 was working every day for months from 9 A.M. to 10 P.M. with the Duke of Gotha's mammoth battery of 600 pairs of plates. Chemistry, he truly said, takes a long time. His experiments with a zinc-silver needle on a pivot led him into strange fancies, and his magnetic battery, consisting of a series of watch-glasses containing water and united each to the next by a series of bent magnetised steel rods, must have puzzled even Humboldt. Ritter promised himself a "recht magnetschen Winter," but he became involved instead in an assemblage of paradoxical phenomena concerning which he appealed constantly to Oersted. Then he visited Italy, and kept Oersted informed of what was happening there with regard to alleged animal "magnetism," water-finding, mineral-finding, and other pseudo-scientific matters, the results either of deception or of lack of precise means of analysis. In due course came the battle of Austerlitz. Ritter wrote to Oersted on December 8, 1805, telling him of the losses sustained, and of his privations.

"München schickt sich unterdessen immermehr zu einem Kriegstheater an, weil heir ein Hauptübergang über die Isar ist. In wenig Tagen sind wir höchst wahrscheinlich den Kuglen des Geschützes ausgesetzt. Die franz. Vorposten sollen bereits in Augsburg seyn."

(Munich is meanwhile becoming more and more a theatre of war, because here there is an important crossing of the Isar. In a few days we shall probably be blown sky high by the cannon-balls of the artillery. The French advanced troops are already at Augsburg.)

"Thank God," he added, "experiments don't cost much." His highest hope was that Napoleon would visit the Akademie at Munich—the Empress Josephine was already in that city. This aspiration concluded—

"Von meiner Seite soll er dann hier sehen, was er in Bologna bloss gehört hatte. Lebe wohl."

Ritter told Oersted that he desired to talk to Volta about the possible electrical origin of animal magnetism, but

"Gegen Leute, wie Er, muss man höflich seyn, u. nach ihrer Sprache bequemen."

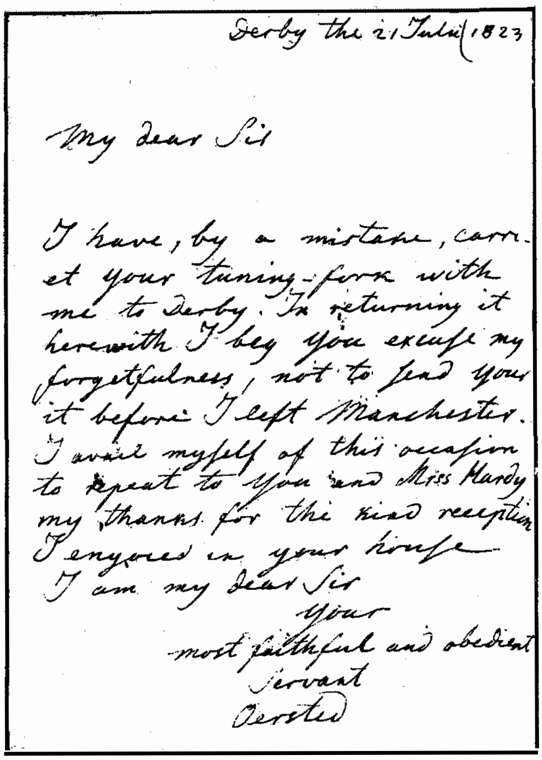
(With people like HIM we must be polite, and mind what we say.)

Behind all this there was Ritter's poverty and his endeavour to find relief by winning the French prize. He wrote piteously to Oersted for assistance,

"Geld ist dass was mir fehlt, u. was mir mehr fehlt, als es nur je gefehlt hat."

and reading between the lines of this correspondence it becomes obvious that Oersted aided him with his accustomed generosity. On the other hand Oersted absorbed some important home truths from Ritter, and especially to temper existence with harmony and colour. Ritter chaffed him about the rigidity of his philosophy, and added

"Vergiss nicht, dass wir Künstler seyn sollen. Kunst aber brauche ich dir nicht zu definiren."


Derby the 21 Juli 1823

My dear Sir

I have, by a mistake, carri-
ed your tuning-fork with
me to Derby. In returning it
herewith I beg you excuse my
forgetfulness, not to send you
it before I left Manchester.
I avail myself of this occasion
to repeat to You and Miss Hardy
my thanks for the kind reception
I enjoyed in your house
I am my dear Sir
Your
most faithful and obedient
Servant
Oersted

Specimen of H. C. Oersted's Handwriting. It is a copy of a letter sent to a Mr. Hardy when H. C. Oersted was in England in 1823.

(Don't forget that we are artists—but I need not define art for you.)

Ritter was perplexed about magnetism; it seemed to him to belong to the other side of nature and to lead to the under-world. Its laws appeared to be opposed to all ordinary laws. He hoped, however, some day to resolve doubts by raising all metals to the magnetic rank of iron, possibly by extreme cold or by extreme heat.

The speculations of Winterl, in 1800, concerning chemical action, made upon Oersted a profound impression. It was Winterl who introduced the two subtle conceptions Andonia and Thelyke—elements more simple than all others, but entering into all. Oersted was captivated by the idea, but he found at Berlin a "terrible prejudice" against it, for Andonia and Thelyke were there denounced as phantoms. From such airy nothings, however, was spun thus early his imaginative faculty, and, above all, the enthusiasm that carried him unscathed across the turbulence of his time.

By his travels and by his close study of contemporary scientific writings, Oersted kept himself informed of progress and utilised his knowledge for the good of his country. He could not always hasten the advance as much as he wished. For example, he was aware in 1811 of the existence of gas lighting (thermolampe) [1] but although it was in evidence in London in 1812, Stockholm waited for it until 1853, and Copenhagen until 1857. After a visit to Gauss at Göttingen in the summer of 1834, he established a magnetic laboratory in a wooden shed in the garden of the Polytechnic School at Copenhagen, and later upon the ramparts of that city. He was a friend of Hansteen, and on his journeys through Europe he introduced Hansteen's apparatus for the observation of terrestrial magnetism. It was in fact at the instigation of Oersted that Arago used it in Paris.

The chief object of his journey in 1822–1823 was to discuss optics, with Seebeck in Berlin; Frauenhofer at Munich; Biot, Fresnel and Arago in Paris; Wollaston, Young and Herschel in London; and Brewster in Edinburgh. Another matter investigated was whether, in accordance with Halley, the earth had four magnetic poles, or whether, as propounded by Euler, it possessed only two, and those unequal. Other puzzles

[1] William Murdoch's first trial of coal-gas, in his home at Redruth, was in 1779. His first installation of gas lighting was at the works of Phillips and Lee, of Manchester, in 1807.

were the causes of magnetic variation and of the polar lights. There was also under consideration the alleged observation by Maschmann that the crystallisation of silver from the solution of the salt is more effective in the magnetic meridian. Later, like most of the pioneers, Oersted directed his attention to the atomic theory, to the dynamics of space and to cohesion.

In 1839, Christian VIII (1786–1848) succeeded his uncle upon the throne of Denmark. He set the finances in order and in general he ruled well. In 1842 he became president of the Royal Society of Sciences at Copenhagen, of which Oersted was secretary. Occasionally the King took the chair at the meetings, but in any case it was Oersted's duty to hand to him a report of all that transpired, and this brought the philosopher and the monarch into constant touch—a circumstance that proved of advantage to the cause of natural science in Denmark. It also facilitated the bestowal of honours. Sir John F. W. Herschel, who became a Knight Commander of Dannebrog, was not allowed to wear the Order in England. This, however, did not deter Sir Roderick Murchison from entering the lists. His birthplace was Scotland, and in reply to preliminary interrogatories he said that, if His Majesty, King Christian, should be pleased to confer any Order on him, it would not be necessary for the case to be tried as he would simply wear the Order. And he did.

Oersted's opinion on the broad issue was: "I cannot but feel the ludicrous in all these titles and distinctions, but I am somewhat reconciled to them by the consideration that they seem to counterbalance the aristocracy of birth and of money. Some day to come will bring a better balance between the honours and merits than this, but I apprehend that this day is not very near."

The friendship between Oersted and Sir David Brewster began at the end of June, 1823, at Edinburgh, where Brewster introduced him to Sir Walter Scott and to other celebrities. In consequence of this visit, Oersted wrote several articles for the Edinburgh Encyclopaedia. They met for the last time at the meeting of the British Association at Southampton in September, 1846. The financial position in Denmark was then serious. Oersted probably lost heavily, and was anxious to restore his income by the sale of his books and writings in England. Yet he always had entertained a poor opinion of publishers—in 1803 he described them as

H. C. Oersted from an Engraving by A. Weger, in Leipsic.

unhappy mortals who understand nothing of the contents of what is offered to them and who depend solely upon the name of the writer. This opinion was strengthened when Mr. Longman refused to publish an English edition of his book on the Philosophy of Beauty. In Danish, German, and French he was a concise writer and prided himself upon the quality of his productions. In English he was fluent but less perfect. Writing, in any case, was not a pleasure to him. "I write," he said, "as if I had to pay for every line. I know some men who write as if every line were to be paid for by others"; and he confessed to "a singular disinclination to writing letters, which has often excited my own astonishment." Nevertheless in 1805 he contemplated writing a Book of Physics for Ladies, and he would have done it if Ritter had not dissuaded him by ridicule.

For Charles Wheatstone, Oersted had considerable regard. The two men had much in common. It is stated by Mr. M. C. Harding that, in 1823, on the occasion of Oersted's visit to London, Wheatstone had just opened a musical-instrument shop where he carried out acoustic experiments so much appreciated by the Danish physicist that Oersted himself introduced Wheatstone to Sir John Herschel and to Babbage. Moreover, it was Oersted who, in 1823, made known in Paris the acoustic and other experiments of Wheatstone; and it was to Oersted that, on May 20, 1839, Wheatstone wrote from King's College, London, describing:

"The way in which I have applied your beautiful discovery for the purpose of transmitting instantaneously, both visibly and audibly, to great distances. The first Electrical Telegraph was established by Mr. Cooke and myself on the London and Birmingham Railway in the year 1837, and we have now a line in action 14 miles in length on the Great Western Railway between London and Bristol."

And on August 16, 1844, from the same address:

"The Electric Telegraph is being brought into extensive use. Our Government has just decided on establishing a line between London and Portsmouth and a commencement is being made in France on the Paris and Orleans Railway."

Miss Petraea Sharling, the gifted daughter of Professor Sharling, has kindly furnished from memory some of the personal details for this account of her grandfather. To Mr. M. C. Harding, and to other members of the Administration of Copenhagen University, thanks are due for many other details, and for kind assistance in obtaining illustrations.

London Toll Exchange

By E. A. ELLIMAN

Engineering Department, Standard Telephones and Cables, Ltd.

Introduction

SIX years ago the Toll exchange in Norwich Street, near Fetter Lane, London, was opened to relieve the London Trunk exchange of the traffic between London and provincial exchanges within an approximate radius of 25 miles and to facilitate the handling of this traffic with greater despatch. The result has been that telephone subscribers in the home counties have been given a very satisfactory no-delay service. In addition, pressure on the London Trunk service has been relieved to an extent such that the long distance switching development has been facilitated considerably and busy London exchanges have been freed from an appreciable load of tandem switching.

With the object of extending the range and advantages of the London Toll service, the British Post Office shortly will open a new exchange[1] at G. P. O. South, Carter Lane, which will work in conjunction with the present equipment in Norwich Street. Both equipments have been manufactured and installed by Standard Telephones and Cables, Ltd., London.

A map of the Toll area is shown in Figure 1, the continuous line embracing the exchanges served by the Toll exchange in Norwich Street, and the extensions to the area resulting from the introduction of Toll G. P. O. South being indicated by the dotted line protrusions from this boundary. It will be observed that three additional areas, all having a large community of interest with London, will receive Toll facilities due to the opening of Toll G. P. O. South—Southend and Chatham districts on the East, Aldershot district on the West and Horsham district on the South.

Before proceeding with a description of the new equipment at G. P. O. South and the new conditions which its opening will involve, a brief description will be given of the existing Toll exchange at Norwich Street and its operating procedure.

[1] The new exchange was successfully brought into service on December 4, 1927.

Toll Exchange, Norwich Street

The switchboard is of the No. 10 common battery type provided with automatic signaling facilities and consists of three distinct groups of positions—one known as "Control" positions, arranged for handling traffic from London local exchanges to provincial towns in the Toll area; another known as "Incoming" positions for traffic incoming from the provincial towns for London local exchanges; and the third, known as "Trunk Junction" positions, for calls incoming from London Trunk exchange.

Signal junction lines are provided for traffic outgoing from London local exchanges to the Toll exchange, these lines terminating at the Toll operating positions in jacks and lamps, similar to the answering equipment at subscribers' positions of a local exchange.

A complete multiple of outgoing Toll lines and junctions outgoing to the London local exchanges is provided throughout the Toll exchange. This is available to every operator so that, if circuits are free, a connection between a London local subscriber and a provincial subscriber in the area can be completed without delay in either direction. Calls which cannot be completed on demand are booked and the connection established as soon as the lines are free, the London subscriber ultimately being called and connected over the outgoing junctions from the Toll exchange.

Traffic from the Toll exchange to the London local exchanges is circulated over groups of order-wire junctions or signal junctions which are connected to the incoming positions at the local exchanges like ordinary local junctions.

Toll lines incoming from the Provinces are terminated in lamps and jacks at the Toll operating positions, like jack-ended junctions or subscribers' lines.

Traffic passing through both the London Trunk exchange and the London Toll exchange is circulated over groups of order-wire junctions. These junctions terminate at the London Toll exchange on special positions similar to incoming order-wire positions at local exchanges.


LONDON-EXTENDED TOLL AREA
London Zone Boundary
Group Boundaries
London Telephone Service Boundary
Existing Toll Area
Extensions to Toll Area
Dotted Circle encloses Exchanges within the 10 mile Radius from Oxford Circus

Figure 1

Operating Procedure Previous to Opening of G. P. O. South

I. *Controlled Traffic*

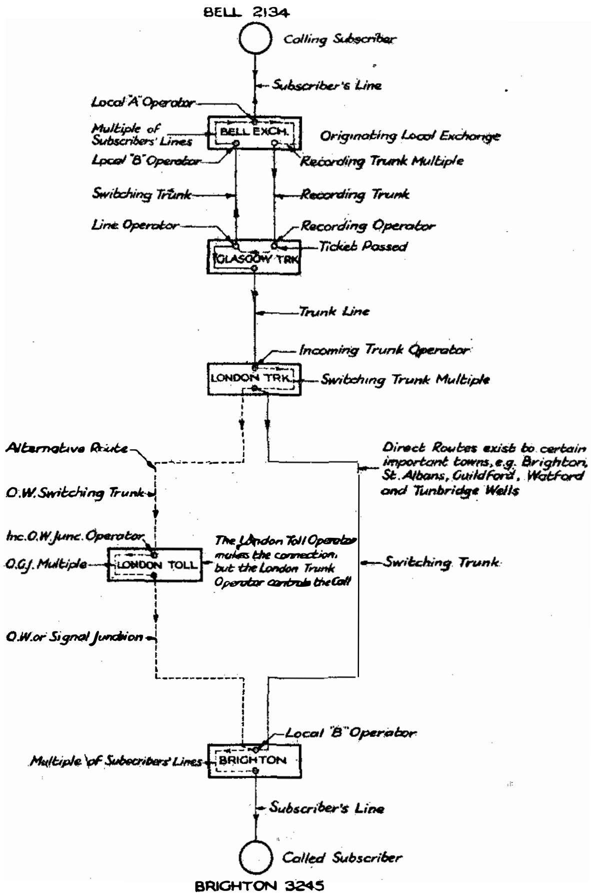
All calls originated by London subscribers for exchanges in the existing London Toll area are controlled at the Toll exchange—Norwich Street. The calling signal is received at a Toll operating position and the line is challenged by the operator, who says "Toll—Number please." The subscriber gives his own number and the number of the required subscriber. The Toll operator writes these particulars on a ticket, repeating them to the subscriber for confirmation or correction. She tests for a disengaged Toll line with the tip of her calling plug and enters the first free line. The provincial operator is signaled automatically by the plugging in to the jack and answers by giving the name of her exchange. The Toll operator passes the number of the subscriber wanted and the provincial operator makes the connection and rings out on the subscriber's line.

When the subscriber required is connected to an exchange subsidiary to that at which the Toll route terminates, the Toll operator asks the provincial Toll centre for the exchange required and waits till the operator at the distant end answers, before passing the number required. When the distant subscriber answers, the London Toll operator satisfies herself that the two subscribers are able to converse satisfactorily and retires from the connection by restoring her listening key to its normal position. She then writes on the ticket the time that the conversation commenced, places the ticket in the clip in front of the cords used to make the connection, and supervises the call.

Should the conversation last three minutes, she enters the circuit and announces that the time is expired and offers an extension if required. If an extension of time is desired, the ticket is marked accordingly and the connections maintained for another three minutes, the procedure being repeated at the end of that period. No limit to the period of conversation is imposed, unless delays occur on the Toll route, in which case operators are instructed to refuse demands for extensions beyond six minutes.

At the completion of the call, the ticket is withdrawn from the clip, marked with a charge tick and placed in the tray for completed call tickets.

Booked Calls. When it is necessary to book a call, the time at which the demand was made is recorded in the "Booking Time" space on the ticket which then is placed in the delayed call ticket receptacle provided at each position. The subscriber is advised that Toll lines are engaged and that he will be rung later. The operator makes attempts at frequent intervals



ROUTING OF A TYPICAL TRUNK TO TOLL CALL
BELL 2134 *requests* BRIGHTON 3245

Figure 2

to secure the Toll line required, noting the time of each attempt on the ticket. As soon as the Toll line is free, she secures it and passes the required subscriber's number and then proceeds to obtain the London subscriber over the outgoing junctions.

Delays. When, owing to the engagement of Toll lines, a call is delayed for 30 minutes the operator, after trying all alternative routes in vain to complete the call, notifies her supervisor. All calls waiting for a route are ticketed and the tickets circulated to the Special Delay position for attention. The handling of these calls will

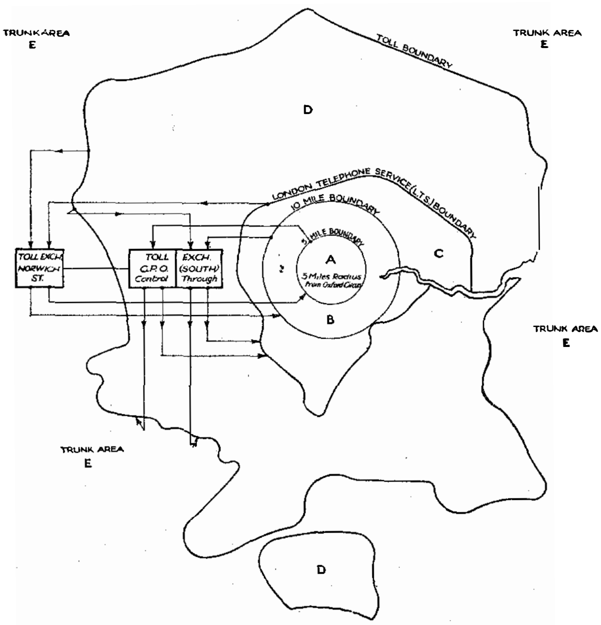


Figure 3—Skeleton Map of Telephone Areas Indicating Routing and Control of Traffic after Opening of Toll (G.P.O. South) and Tandem Exchanges. (See also Table No. 1.)

be described later under the heading of "Delayed Traffic."

Signaling Arrangements. When a connection is given on demand and the conversation is held over the junction on which the demand was received, the answering supervisory signal does not glow until the junction is cleared at the local exchange. The calling subscriber's supervisory signal is received by the local operator, who clears the junction to the Toll exchange.

When a call is booked and subsequently effected over the outgoing local junction multiple, the London subscriber's supervisory signal is received direct on the answering supervisory lamp. In the majority of cases, a clearing signal is received direct from the provincial subscriber. In order that the other cases may be provided for, close supervision is exercised on all calls.

II. *Incoming Traffic*

No record of incoming provincial traffic is kept at the Toll exchange in Norwich Street.

The operator, on observing a line lamp glow, inserts an answering plug into the corresponding jack and challenges the line with the remark "London." Receiving details of the required connection from the distant operator, she repeats them and proceeds to secure the connection to the local exchange over the outgoing junctions.

The control of all traffic on incoming Toll lines rests with the provincial operators, who, in cases of "No Reply," "Line Engaged," etc., are responsible for any further attempts to complete the calls. After establishing the connections for an incoming call, the Toll operator does not enter the circuit again, unless a flashing or clearing signal is received.

Supervisory Signals. The answering supervisory lamp is darkened when the Toll operator answers and remains dark until the Toll line is released at the provincial exchange.

The calling supervisory lamp glows when an order-wire junction is picked up and darkens when the London subscriber answers. It glows again when the London subscriber hangs up his receiver.

When a signal junction is used, the calling supervisory lamp darkens when the distant operator answers and glows again when she leaves the circuit, continuing to glow until the

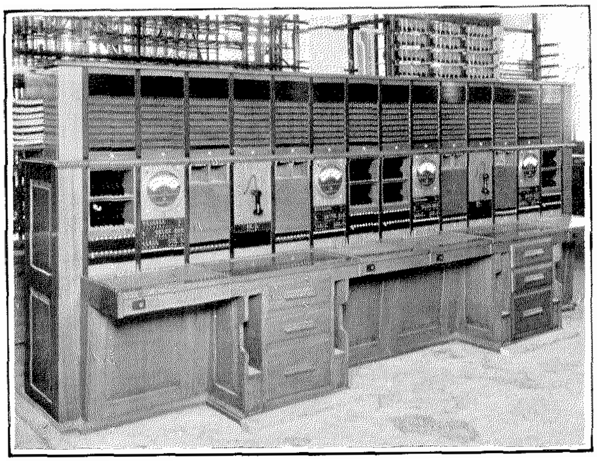


Figure 4—Test Desk, Toll Exchange G.P.O. South.

called subscriber answers or the distant operator enters the circuit again.

The signals given by the London subscribers are received at provincial common battery exchanges, but not at magneto exchanges.

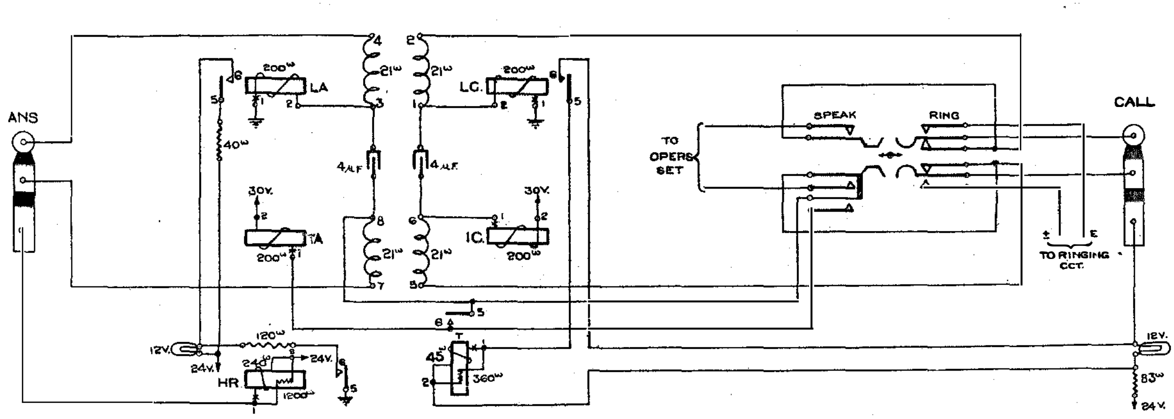


Figure 5—"B" Cord Circuit.

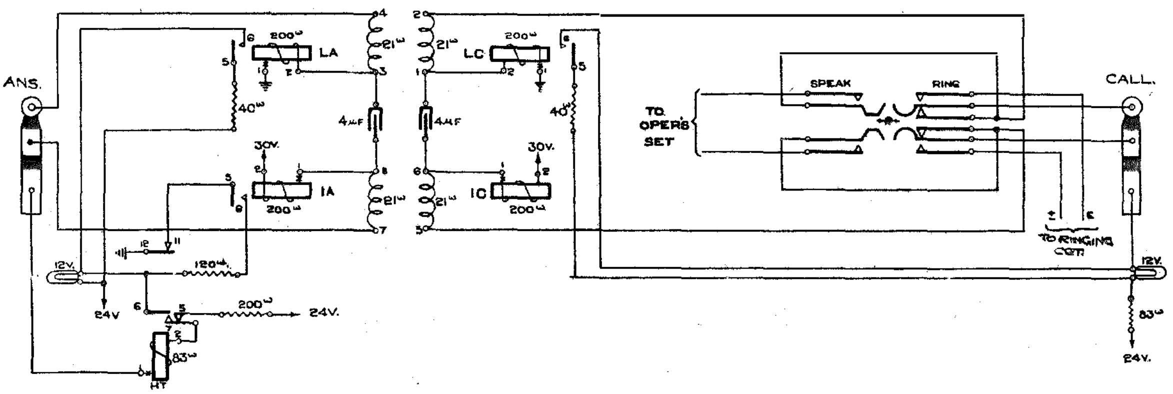


Figure 6—Control Cord Circuit.

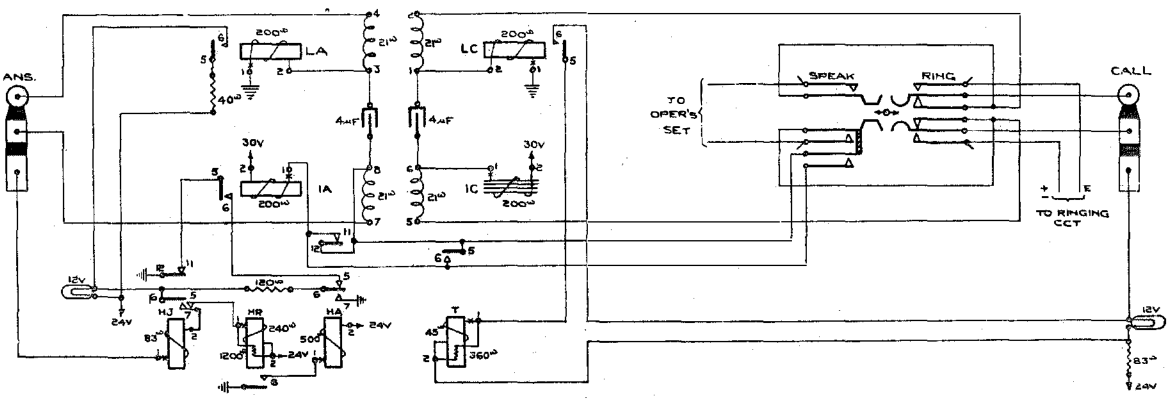


Figure 7—Universal Cord Circuit.

Double Clearing. Upon receipt of clearing signals on both supervisory lamps, the connections are broken down without challenge.

Single Clearing. (*a*) Answering (Provincial) Supervisory: The Toll operator enters the circuit saying, "Have you finished?" Receiving no reply, she breaks down the connections. If the London subscriber is still on the line and complains that he has not spoken or that he has been cut off, the operator instructs him to replace his receiver, stating that he probably will be called again. (*b*) Calling (London) Supervisory: The Toll operator challenges the line and, receiving no reply, breaks down the connection.

Through Provincial Calls. (*Tandem Working*). Calls incoming from provincial exchanges for other provincial exchanges in the London Toll area are handled at the incoming Toll positions. If a Toll line to the required exchange is available, the connection is given at once; otherwise, the busy back signal is given. These through calls are controlled at the originating provincial exchange, the London Toll exchange functioning in this case as a tandem office.

On the receipt of a signal on the answering supervisory lamp, the Toll operator challenges the line and breaks down the connection.

Calls from Provincial Exchanges Routed by London Toll to London Trunk Exchange. Provincial operators connected with London Toll exchange requiring an exchange in the London Trunk area ask the Toll operator for "Zone Records." The Toll operator tests for a disengaged line in the group of zone record junctions, which is located in the outgoing local junction multiple. Finding a disengaged junction, she completes the connection, thus putting the provincial operator into communication with the record operator at the London Trunk exchange.

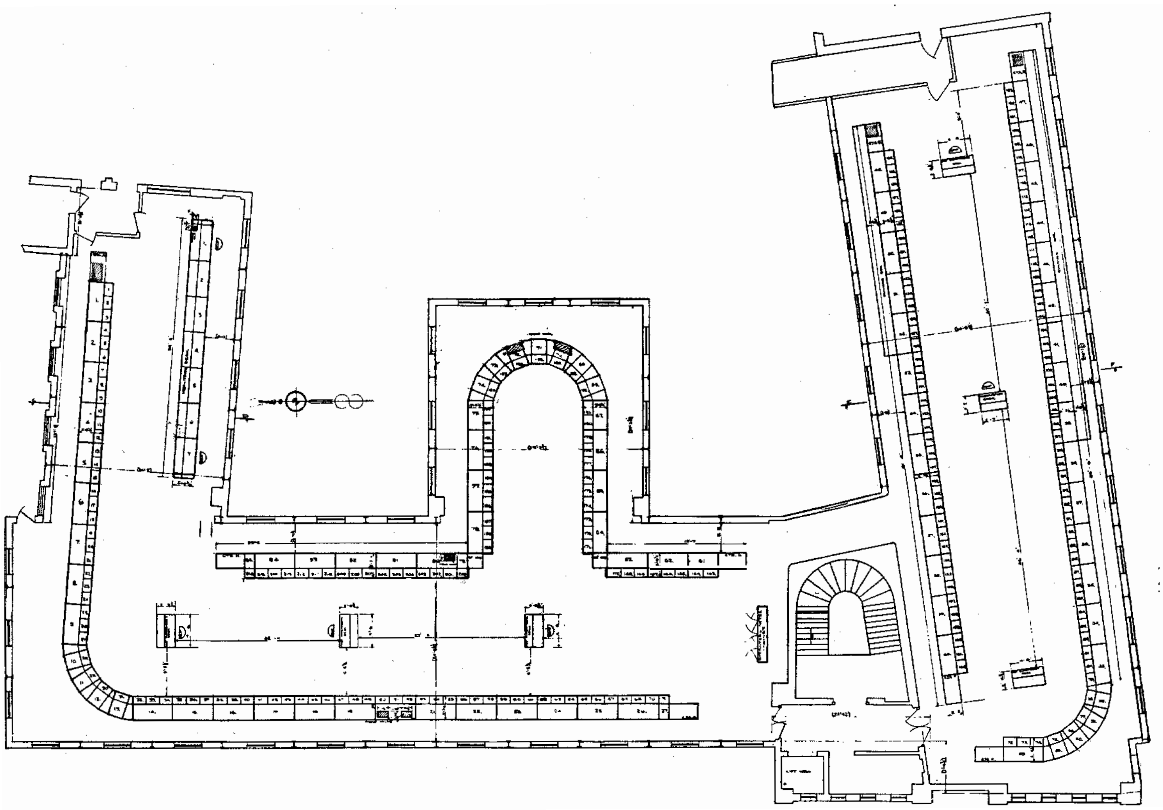


Figure 8—Layout of Switchboards and Desks, Toll Exchange G.P.O. South.

III. *Trunk to Toll Traffic*

The calls handled at the special positions provided for this traffic may be divided into two classes:

(1) Calls originating at provincial exchanges outside the London Toll area for provincial exchanges served through London Toll exchange.

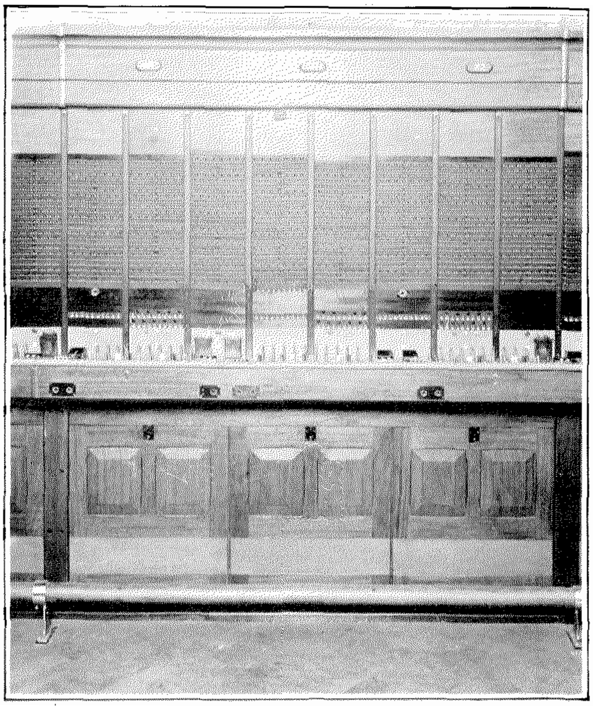


Figure 9—Typical Section of "Control" Positions—Front View—Toll Exchange G.P.O. South.

(2) Calls originating at exchanges in the London Toll area for provincial exchanges served through London Trunk exchange. As already mentioned, calls in this class are routed by Incoming Toll operators to zone records. The record is made at the Trunk exchange and, where direct lines from the Trunk exchange to the town required do not exist or for any reason are not available, the call is reversed, re-entering London Toll by the special positions considered in this section. This means that these calls are now handled in exactly the same manner as those in Section I (Controlled Traffic).

The Trunk junction operator at London Toll receives a demand over the order-wire for connection to a provincial exchange in the London Toll area. She allots a junction to the Trunk operator and proceeds to test for a disengaged line in the Toll route required. If a line is available, she makes the connection with the junction allotted without ringing on the Toll line and leaves the Trunk operator to pass the number and control the call. If a Toll line is not available, she connects the junction allotted with the "Engaged" signal.

Should the delay procedure be in operation on the Toll line demanded, she connects the junction allotted with a delay operator at London Toll, who completes the connection as soon as a line becomes available.

Figure 2 illustrates the sequence of events in routing a call from a subscriber in Glasgow to a subscriber in Brighton, showing alternative routes:

(1) Through London Trunk exchange and direct junction to Brighton.
(2) Through London Trunk exchange and London Toll exchange.

The arrow heads indicate the direction in which the connection is being established.

Supervisory Signals. Each incoming junction circuit is provided with a supervisory lamp, which is controlled by the operator at London Trunk exchange. Upon receipt of the clearing signal on this supervisory lamp, the Trunk junction operator at London Toll breaks down the connection.

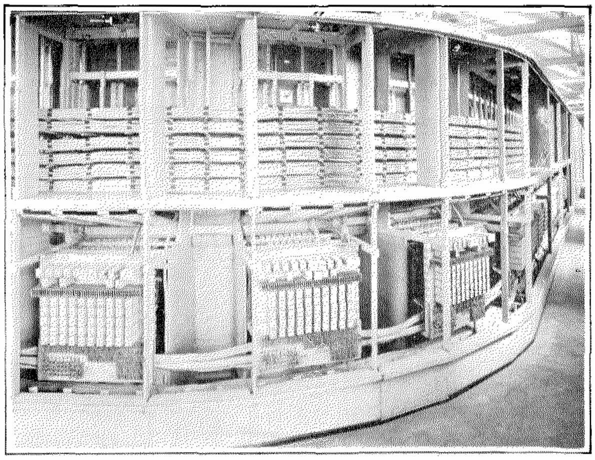


Figure 10—Rear View of Control Positions in South Wing.

IV. *Delayed Traffic*

When the delay on a Toll route amounts to 30 minutes, the Toll operator books the calls received and circulates all tickets for that route to the delay positions. The delay operators take control of all such routes and connect the calls in the booking time order. As soon as the delay is reduced to 5 minutes, the Toll operators are instructed to resume control.

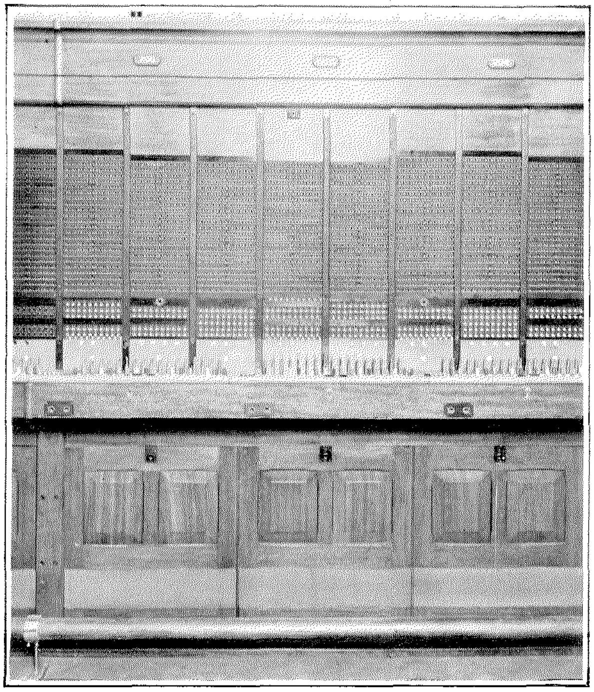


Figure 11—Typical Section of "Through" Positions.

The Toll operator at an incoming position, receiving a call for a "Delay" route, connects the junction allotted to a transfer line terminating at one of the delay positions. The delay operator, upon receipt of a calling signal on the transfer line, enters the circuit and enquires the name of the wanted exchange. If the route desired is available at the position, she appropriates the first free line for the call and through the section supervisor arranges for the Trunk-toll junction to be transferred from the transfer line to the Toll line appropriated.

If the Toll route concerned is under the control of another delay operator not adjacent to the one who answers the transfer line signal, the operator answering the call furnishes her section supervisor with the name of the route in which a line is required and the number of the transfer line.

The supervisor arranges for the appropriation of a Toll line and for the transfer of the junction to that line.

Information Service

Facilities are provided to furnish an efficient information service.

The equipment for this purpose consists of two four-position desks fitted with the following circuits:

(*a*) Lines incoming from the switchboard terminating in lamps and jacks. (Complaint lines, enquiry lines, etc.)
(*b*) Lines outgoing to a control position
(*c*) Lines for transferring calls from position to position at the information desk
(*d*) Lines to the supervisors
(*e*) Lines for communicating with each position operator in the exchange
(*f*) Bothway lines to information desks at other exchanges.

All lines are multiplied so as to be accessible to every operator at the information desk.

Class of Calls

The calls handled at these positions are those of an irregular nature received by the Toll operators as, for example, calls for supervisor, fee enquiries, directory enquiries, and information or complaints relating to service.

As far as possible, the Toll operator receiving such calls differentiates between complaints and enquiries, and connects the subscribers to the appropriate lines going to the information desk. Assistant supervisors usually attend to complaints, whilst the work of enquiries is generally handled by senior operators.

Figure 12—Operating Room—General View Facing North—Toll Exchange G.P.O. South.

Procedure

Every complaint or enquiry is recorded on a docket and dealt with according to its merits. Where it is necessary to give the subscriber a connection on the Toll system, it is not effected through the information desk but through the Toll switchboard in the regular manner, thus obviating transmission difficulties.

Norwich Street and G. P. O. South, the Norwich Street exchange handling the traffic from the provincial towns in the Toll area to exchanges within the 5 and 10 mile circles with Oxford Circus as the centre, and from the London telephone service area to exchanges within the 5 and 10 mile circles. In fact, all calls for subscribers within these two circles passing through the Toll area will be completed at the Norwich Street exchange, since the multiple of junctions to the London exchanges is located at this exchange and not at G. P. O. South.

At London Toll exchange G. P. O. South, four classes of traffic will be handled:

1. Controlled traffic; i.e., calls from London subscribers within the 5 mile circle to the Toll area

TABLE I

ROUTING AND CONTROL OF TRAFFIC AFTER TOLL (G. P. O. SOUTH) AND TANDEM EXCHANGES ARE OPENED

A—Exchanges within the 5 mile circle
B— " between the 5 mile circle and the 10 mile circle
C— " outside the 10 mile circle and within the L. T. S. area
D— " outside the L. T. S. area and within Toll area
E— " in Trunk area

From	To	Route	Control: Automatic	Control: Manual
A	A	Direct or via Tandem	Dialed by Subscriber	Originating Local Ex.
A	B	" " " "	" " "	" " "
A	C	Toll (G. P. O. Sth.) or Direct	Toll Exchange	" " "
A	D	" " "	" "	Toll Exchange
B	A	Direct or via Tandem	Dialed by Subscriber	Originating Local Ex.
B	B	" " " "	Unit Fee: Dialed by Subscriber Excess Fee: Originating Local Ex.	" " " " " "
B	C	Toll (G. P. O. Sth.) or Direct	Originating Local Ex.	" " "
B	D	" " " " "	" " "	" " "
C C	A B	Initially Tandem or Direct Ultimately Toll (Norwich Street) or Direct	" " "	" " "
C C	C D	Toll (G. P. O. Sth.) or Direct *	" " "	" " "
D D	A B	Toll (Norwich St.) or Direct	" " "	" " "
D D	C D	Toll (G. P. O. Sth.) or Direct	" " "	" " "
A, B & C	E	Direct or Tandem to Trunk Records	" " "	" " "
D	E	Toll (Norwich St.) or Tandem to Trunk Records	" " "	" " "
E	A & B	Trunks by Direct Junction or via Toll (Norwich St.)		
E	C	Trunks by Direct Junction or via Toll (G. P. O. Sth.)		
E	D	Trunks by direct line to objective exchange or switching centre		

* Or in some special cases via Local Toll Centre.

New Toll Exchange—G. P. O. South

EFFECT ON TOLL AREA TRAFFIC

It is anticipated that the British Post Office will open its Tandem exchange in London at the same time that the Toll G. P. O. South equipment is placed into service, and the routing and control of telephone traffic then will be arranged as indicated in Table I and Figure 3. The control of the Toll area traffic at this period will be divided between the two centres,

2. Through Calls:
   (*a*) Calls from subscribers between the 5 and 10 mile circles to places within the Toll area. Modification may be made later to include these calls with controlled traffic.
   (*b*) Calls between places within the Toll area.
3. Trunk to Toll traffic where direct circuits to places in the Toll area are not provided from the Trunk exchange multiple
4. Delayed traffic, the local London subscriber being obtained in this case via Norwich Street, as already explained, although the actual booking will be done at G. P. O. South.

Figure 13—Operating Room—North Wing.

Operating Procedure

It is expected that the operating procedure will be very similar to that at present in force at the Toll, Norwich Street exchange, and it is very probable that the information service will be centralised at the G. P. O. South exchange, where a 14-position monitor's desk is installed.

Equipment

The new Toll equipment is accommodated in the building which also contains the London Trunk exchange and the two local exchanges known as "City" and "Central," respectively.

The power supply at 24 volts will be received from the Central exchange batteries and a supply at 30 volts will be derived from additional cells provided by the Post Office. Ringing current will be furnished to the exchange by the Central exchange ringing machines. Additions and modifications to City and Central power plants for battery charging purposes have been carried out under the contract for the Toll exchange. The 24-volt supply will be fed by twin concentric lead-covered cables running from the basement to the third floor, where they are terminated at a bifurcating box located on the wall of the repeater room.

The apparatus room is located on the fourth floor and contains the repeating coil rack and fuse panel, the intermediate distributing frame, two relay racks and the time check rack.

The main distributing frame equipment is mounted on the existing frame on the gunrod floor, and a 4-position test desk surmounted by a test jack cabinet has been installed in an adjacent position. Figure 4 shows the front view of the test desk, the test jack cabinet and a portion of the main distributing frame.

The switchboard, which is of the No. 1 common battery type, occupies two rooms on the fifth floor. It consists of:

158 Control positions, each equipped with 10 cord circuits

2 Delay positions, each equipped with 10 cord circuits

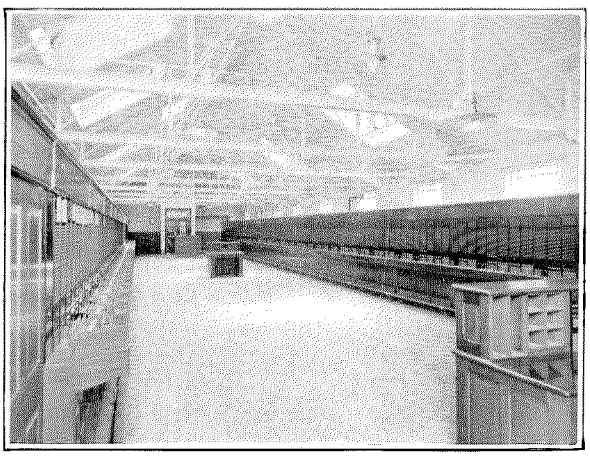


Figure 14—Operating Room—South Wing.

29 Through positions, each equipped with 17 cord circuits

11 Junction positions, each equipped with 30 plug-ended junctions

1 Service P.B.X. position, equipped with 17 cord circuits
1 Fault position

It is equipped for 1,580 calling equipments for jack-ended junctions (control positions), 870 calling equipments for jack-ended junctions (through positions), 330 plug-ended junctions and 2,800 outgoing junction multiple (6 panels per multiple).

The "transmission" includes a repeating coil associated with condensers and impedance coils

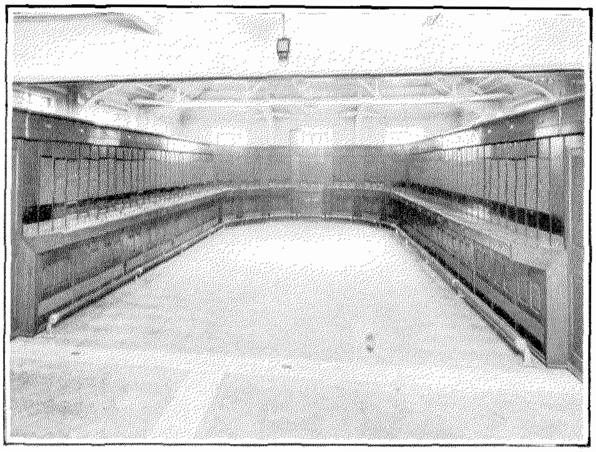


Figure 15—"Through" Positions in Horseshoe Bend.

and relays acting as impedance coils associated with a 30-volt battery. Diagrams of the "B" cord circuit, control cord circuit and universal cord circuit are shown in Figures 5, 6, and 7, respectively.

The arrangement of the switchboard is shown in Figure 8, which also shows the positions of the desks and operator's meter cabinet. Sections numbered 1 to 62 are wired and equipped as control positions, including two delay positions. The front equipment of a typical section of this type is shown in Figure 9, whilst Figure 10 shows the rear view of a suite of control positions with rear doors removed. The answering jacks and lamps are ancillaried, giving primary and secondary appearances. For night working the circuits will be concentrated on sections 9 to 26, inclusive. Each position is furnished with a Veeder clock for call-timing purposes. Sections numbered 63 to 68 are designed as regular junction sections, No. 63 being unequipped at present, whilst positions 172 to 182, inclusive, in sections 64 to 68 have been equipped with

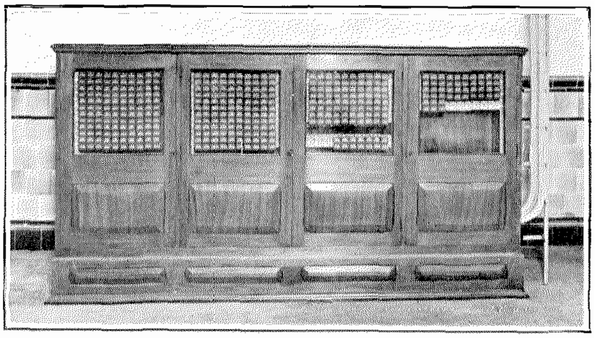


Figure 16—Operator's Meter Cabinet.

30 plug-ended junctions per position. Sections numbered 69 to 84 are arranged for "Through" positions, the front equipment of a typical section being shown in Figure 11. No provision is made for ancillary working on these positions. For night working the circuits will be concentrated on sections 81 to 84, inclusive.

Section No. 84 provides a position equipped as service P. B. X. and another position equipped for fault service.

General views of the operating room taken from various aspects are shown in Figures 12, 13, 14 and 15. The 4-bay cabinet for operators' meters is seen in Figure 16. Figure 17 shows the 14-position monitors' desk equipped for information service; the commencement of the suite of control positions is seen in the background.

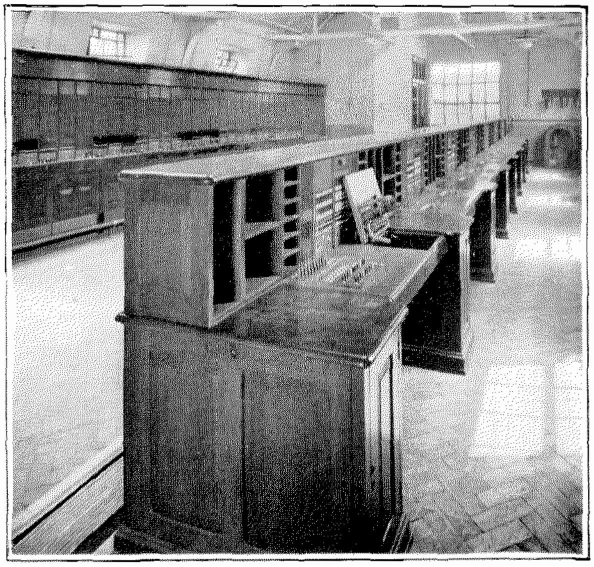


Figure 17—Information Desk, Toll Exchange G.P.O. South.

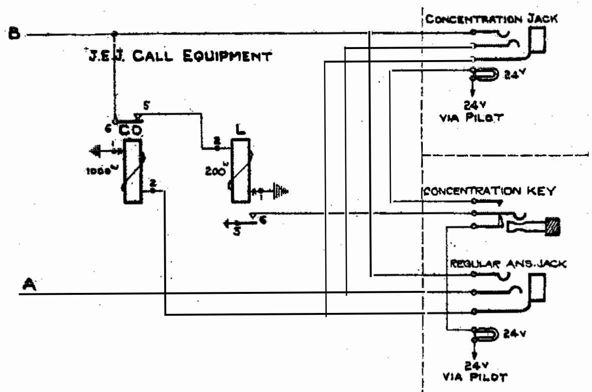


Figure 18—Incoming Jack-ended Junctions from Manual Exchanges—"Through" Positions.

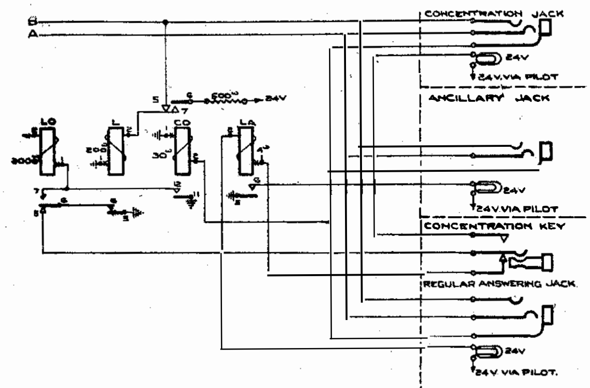


Figure 19—Incoming Jack-ended Junctions from Manual Exchanges.

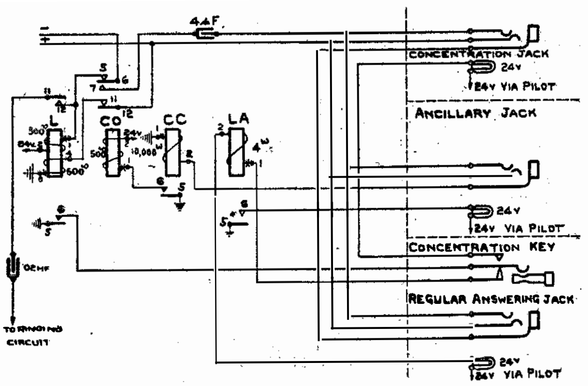


Figure 20—Incoming Jack-ended Junctions from Automatic Exchanges.

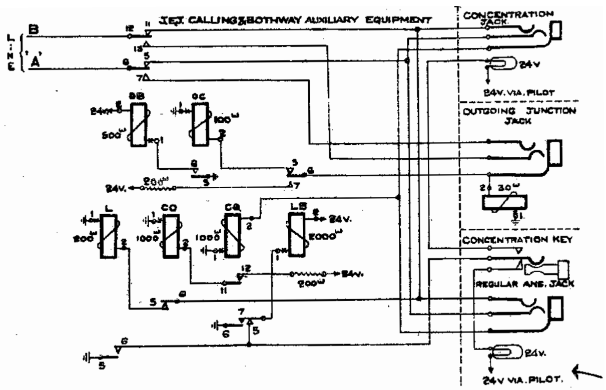


Figure 21—Bothway Jack-ended Junctions to and from Manual Exchanges.

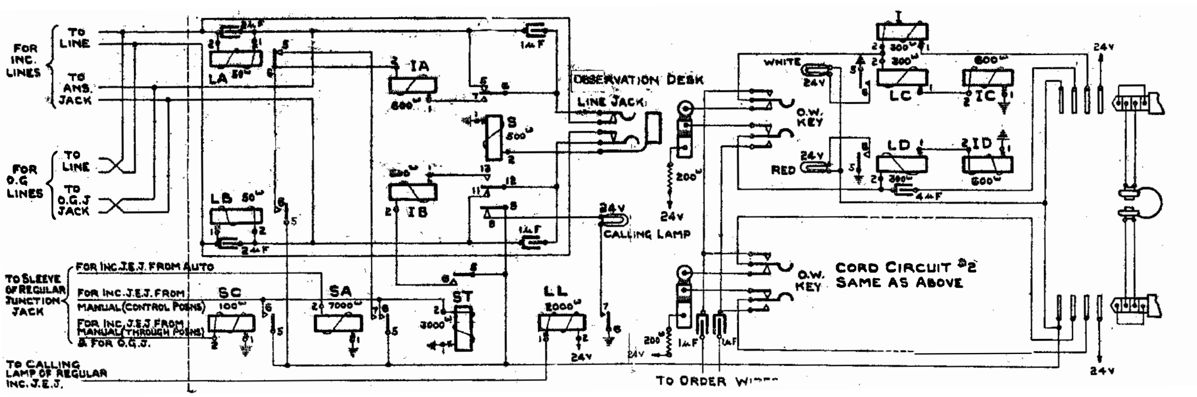


Figure 22—Line and Cord Circuit—Observation Desk.

Cabling and Circuits

The cabling of the switchboard has been arranged to give any combination of cross-connection; the answering equipments, primary, secondary and concentration keys and all the relay equipments are wired direct to the intermediate distributing frame.

The relays provided in the exchange circuits are of the flat type; and the installation furnishes the first instance of a manual equipment provided by Standard Telephones and Cables, Ltd., where flat type relays exclusively are used.

together with the associated timing mechanism. These Time Checks are mounted together on a rack in the apparatus room and are controlled at the switchboard by a key per cord circuit. The diagram of connections is given in Figure 23.

When the operator depresses the start key, the lower relay of the Time Check is energised, completing a holding circuit, breaking the lamp circuit, and making the circuit for the upper relay. The upper relay receives impulses at one-second intervals from the Master Clock to

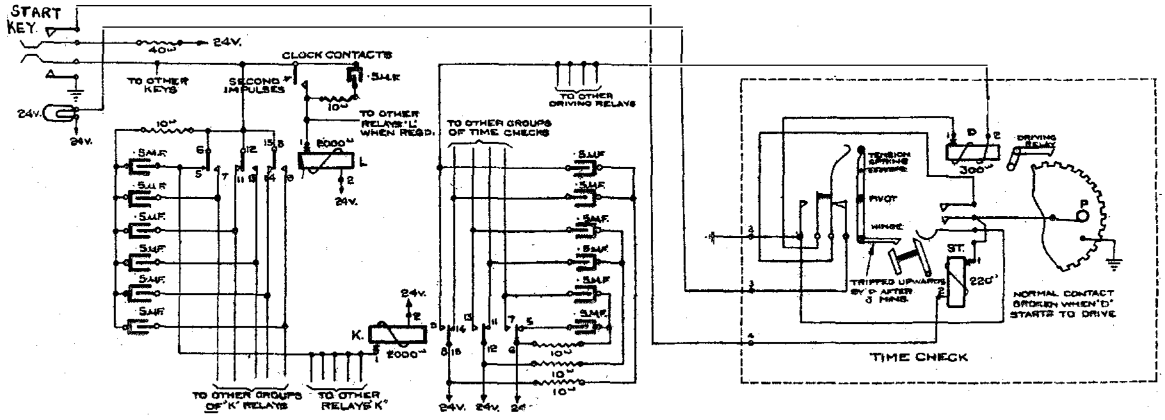


Figure 23—Time Check Circuit.

The provision of the "operator hold" facility from the cord circuits on those calls dialed out from automatic exchanges necessitated very sensitive relays in the cord circuits to ensure correct supervision, which has been secured by means of relays designed to operate on a low current.

Incoming junction circuits are shown in Figures 18, 19 and 20 and the bothway junction circuit in Figure 21.

The line and cord circuit for the observation desk is shown in Figure 22. It was redesigned to take care of the various new conditions encountered in this type of Toll operating.

An interesting departure from the general methods of timing the duration of telephone calls has been made in the case of the G. P. O. South equipment. Associated with each cord circuit on the control and delay positions is a Time Check, consisting of two relays of the Message Register type assembled as one unit,

drive the mechanism. At the end of three minutes (180th impulse) the hinge is tripped upwards, allowing the springs to return to normal, thereby breaking the circuit of the upper relay and completing the lamp circuit. On observing the lamp signal, the operator restores the start key to release the lower relay.

If a demand for extension of time is received the operator, after resetting, depresses the start key again and the Time Check passes through the same cycle of operation.

Acknowledgment

The author is indebted to the Traffic Section of the British Post Office for the traffic detail and map of the Toll area included in this article, and desires to take this opportunity of acknowledging the courtesy of the officers concerned. Thanks are due also to the Engineer-in-Chief of the British Post Office for permission to publish this article.

Pole Timber and Its Preservation

By C. A. SMITH

European Engineering Department, International Standard Electric Corporation

Introduction

When consideration is given to the quantities of timber being used each year for supporting the aerial line plants of the world, to the still greater quantities annually consumed for general purposes, and to the immense number of wood poles and cross arms already in place in the United States and in Europe, the question arises whether all this timber has been and is being provided with adequate protection against premature decay. In countries where plentiful supplies of pole timber are near at hand and where labour is cheap, the question of preservation is never seriously considered. In other countries, where suitable pole timber is scarce and where the cost of transport is high, methods have long been applied to extend the useful life of wood poles.

It was the birth and growth of the railway systems of England that first called for an effective method of preserving timber, particularly wood sleepers, from decay. The use of the heavy oils of tar, commonly called creosote, was first introduced for this purpose by John Bethell in 1838. The ever-growing demand for pole timber—apart from other kinds—with recurrent increase in prices, has become a matter of considerable concern to line plant engineers, particularly in view of the serious shortage of suitable stocks, notably in Europe and certain of the American States. The depletion of forest supplies from many parts of the world and the slowness of the process of reforestation are not, however, the only reasons for anxiety. The problem of decay and the economic question of the preservation of timber is equally a matter of concern.

In regard to economy, the factor of first importance to consumers is the physical life of wood poles and the resulting effect upon the annual charges of aerial plant and the charges to be made for the service rendered to the public. Any increase secured to the life of a wood pole due to preservative treatment, if obtained at less than the cost of replacing the equivalent untreated poles throughout the same period, is economical; or otherwise stated, let

T = Life of aerial line support using preserved wood poles

t = Ditto using unpreserved wood poles

If $(T - t)$, the extension of useful life arising from the employment of preserved poles, is obtained at less cost than that of replacing unpreserved poles during the time $(T - t)$, the system with preserved poles ought to be chosen. Preserved poles, moreover, are conducive to better service, because there are fewer chances of interruption incident to replacement than with plain wood poles.

Primitive man no doubt discovered that the stakes he pointed by fire lasted much longer than others, but he could not tell why charring should be effective. With the advance of time, and from necessity, man has progressed in knowledge of the causes of timber decay. Much has been achieved in delaying the inevitable consequences of neglect, and today the results of organised research are seen in the benefits derivable from practical methods of treatment.

Pole Timber

While cedar and chestnut are the most favoured woods in America for telephone poles, in Europe the timber preferred for this purpose is cut from the extensive fir and pine forests of Scandinavia and Russia, and the tree chosen by the British Post Office is the red fir of commerce known as *Pinus Sylvestris*. The red fir, together with other firs, the pines and the larches, which are the principal members of the conifer group and are distinguishable by their needle-shaped leaves, thrive best in cold or temperate climates. By the nature of their stately forest growth, they are tall and straight and particularly free from low branches (Figure 1).

The growth of these trees is comparatively rapid and their straight stems, during the vigorous period, often extend 2 to 3 feet in a season; but while, in favourable soils and situations, they reach maturity in from seventy to eighty years, those marked for telephone poles are cut at a much earlier period.

Figure 1—At the Fringe of a Swedish Pine Forest.

It is a generally accepted condition that timber shall be felled in winter when the sap is down, in order to facilitate seasoning and the subsequent process of preservative treatment. It is known also that the strength of timber is affected by its moisture content; and from a series of tests it appears that wood containing about 15 percent of moisture is at its maximum strength. For these reasons, felled timber must not be allowed to lie in wet locations before removal to the drying grounds.

The timber from northern Europe is floated down the rivers to the local ports, from whence it is collected and shipped in loads of about

6,000 or 7,000 poles. British consignments are landed at various coastal depots where the seasoning grounds and creosoting yards are located.

Wood poles have the immense advantage of great flexibility and, mechanically, are very suitable for the purpose of aerial line support, for the loads they are called upon to withstand are similar in character to those borne by the trunks of the original trees. A valuable feature of the fir or pine pole is its elasticity.

Since the mechanical properties of timber vary considerably, it is necessary in all calculations to employ a very conservative figure for its ultimate strength. The maximum fibre stress, as determined from "breaking tests" and referred to as the Modulus of Rupture, varies with different woods from 4,000 lbs. per sq. inch for the softest kinds, to about 18,000 lbs. per sq. inch for the hardest species. After extensive experiments many engineers have adopted the figure of 7,800 lbs. per sq. inch for red fir, creosoted.

The usual form of specification issued to the suppliers of pole timber states that every tree felled must contain the natural butt; i.e., the tree must be sawn off as close to the ground as possible. The timber must be sound, hard-grown, straight and free from knots, and the bark must be completely removed; also, the whole of the operations connected with delivery, preparation (storage seasoning) and creosoting of the pole timber, must be carried out under supervision.

It may be of interest to refer briefly to the manner in which poles are measured, and to explain the meaning of the terms "string" and "caliper" measures as applied to timber:

(*a*) String measure consists in girthing the pole at half length with string or tape. The content is given by:

$$\frac{L}{113}\left(\frac{g}{4}\right)^2 = \text{cubic feet}$$

(*b*) Caliper measure consists in taking the diameter of the pole at half length by means of a pair of calipers. The content is obtained from:

$$\frac{L \cdot d^2}{183} = \text{cubic feet}$$

L, is the length of the pole in feet; g, the girth; and d, the diameter measured in inches at half the length of the pole.

The weight of untreated fir or pine wood varies from 30 to 40 lbs. per cubic foot.

Reforestation

In the countries chiefly concerned with timber production, especially those where climate and soil conditions are best suited for the growth of soft woods, reforestation is now being vigorously pursued in order to maintain supplies after existing stocks are exhausted. During the winter of 1925 more than 39,000,000 new trees were planted in Great Britain as part of the programme begun by the Forest Commission about six years ago for restoring the forests of England, Scotland and Wales. The trees occupy a space of 22,000 acres of what would otherwise be chiefly waste land. Since it commenced work the Commission has planted 52,500 acres and has assisted local authorities to plant another 5,000 acres. These activities have resulted in the production of 184,000,000 new trees.

The programme, spread over ten years, provides for the planting of 250,000 acres with 450,000,000 trees, mostly of different varieties of fir and spruce, grown from seed in nurseries and then planted out. It is estimated that in twenty years from the first planting the enterprise will begin to show returns. At present Great Britain imports £50,000,000 worth of timber annually.

Characteristics of Wood

Wood consists of a complex system of minutely formed vessels or cells with fibrous walls which constitute the solid parts of the structure. With the exception of the sapwood—a comparatively soft layer near the surface and under the bark—the solid parts comprise the heart wood, at the centre of which are the crushed-up remains of what was once the pith. The function of the sapwood comprising similar tracheids or cells—the lungs of the plant—is to draw up by capillary action the water with dissolved salts from the roots. In the natural order of things—the cyclic changes of the seasons beginning with the rise of sap in springtime, the chemical changes induced later by the sun, and the diurnal absorption of air and moisture by the leaves—new cells are formed containing the protoplasm, the physical basis of life; and, by a process of coagulation, first a covering of cellulose and then of lignose or wood fibre is produced. Between

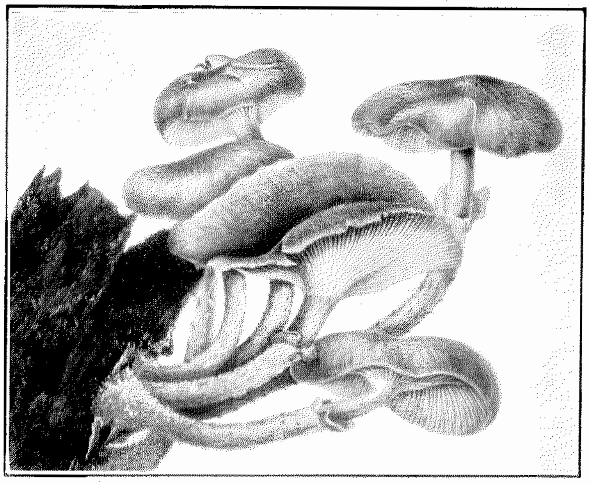


Figure 2—Fungoid Growth on Decaying Wood. (With acknowledgments to the Director of The Royal Botanic Gardens, Kew, Surrey, England.)

the bark and the wood, therefore, a new layer is formed, called the cambium, which constitutes the season's growth. Hence the annual rings. In the conifer woods, these concentric rings are sharply defined and by counting them the age of the tree is determined.

Decay of Timber

Decay, or dry rot, in timber is due to bacteria derived from various kinds of fungi (Figure 2) which feed upon the contents of the wood cells. The spores are blown about by the wind, and thus are brought into contact with the timber where, under favourable conditions, they penetrate into the cells and reduce the wood to a crumbling mass (Figure 3). For their growth, air, moisture and warmth are essential, and, as all three are usually present at, or just below, the ground level, it is there that wood poles are most susceptible to rot.

If air, moisture or warmth is absent, the bacteria or fungi cannot thrive, and decay is arrested. As an example of a case where air at proper temperature but no moisture is present, the coffins preserved from the times of the Pharaohs may be cited, while timber submerged in water at a suitable temperature but unexposed to air has defied decomposition for hundreds of years. Wood piles are excellent examples of the latter class. Again, wood exposed to water and air, but at very low temperature, is not liable to suffer from decomposition, a fact abundantly shown by the preservation of prehistoric canoes in ice-fields.

Another form of decay, not often met with in Europe but a serious menace in tropical countries, is due to termites; i.e., insects (Figure 4) that attack the pole, usually from the ground, where they penetrate and feed on the moist timber and quickly weaken it.

Felled Timber Preservation

For the destruction of fungi and the prevention of decay, it is necessary to poison the

Figure 3—Two Progressive Stages of "Dry-rot." The thread-like filaments are known as mycelium.

food supply of these parasites by injecting some kind of antiseptic. The coarse grain of the firs, pines and similar soft woods is very suitable for this treatment. The antiseptic employed for the purpose may be a water solution applied cold or hot in a bath or by injection, or by the

Figure 4—Piece of an Untreated Pole Butt Ravaged by Insects.

approved British method of injecting hot creosote oil.

A preliminary to the application of any of the various methods of preserving timber is prolonged exposure to natural air-drying which sometimes, however, is followed or replaced by exposure to live steam, for the purpose of seasoning. Air-drying alone is considered to be the most satisfactory process of seasoning, provided that it is not hurried.

There have been introduced in the past many preservative processes, generally of watery solutions bearing names according to the salts employed, and often with extravagant claims of superiority. In practice, however, none of these processes have been proved effective in prolonging the life of the timber to the extent desired. In general, the great disadvantage of watery solutions is the tendency for them to wash out due to the effects of rain, notwithstanding ingenuous means devised for overcoming this defect.

Other objections to the use of these solutions are: (1) the difficulty of providing special plant which will resist the corrosive action of the liquids when the injection method is employed, (2) the corrosion of pole iron fittings, (3) danger to workmen, and (4) the poisoning of streams and of animals grazing on pasture lands, due to noxious chemicals draining out of standing poles which have been thus impregnated.

In view of these objections only the following very brief reference will be made to the best known of these processes:

Process	Chemicals Used
Kyan	Corrosive sublimate
Boucherie	Copper sulphate
Burnett	Zinc chloride
Ferrell	Aluminium sulphate with sodium chloride and other salts
Hasselman	Sulphates of copper, aluminium and iron, with kainite
Falk Novoling	Sodium fluoride and phenol

The "Aczol" process more recently introduced promises to rival the creosoting process if the advantages claimed for it are substantiated in practice. This process, invented by a Belgian chemist, utilises a solution of Ammonia-Copper-Zinc-Phenol, and is dark green in colour. It is applied cold, either in an open bath or, preferably, by the more effective method of pressure-injection. It has greater penetration than creosote. It is supplied and stored in iron drums.

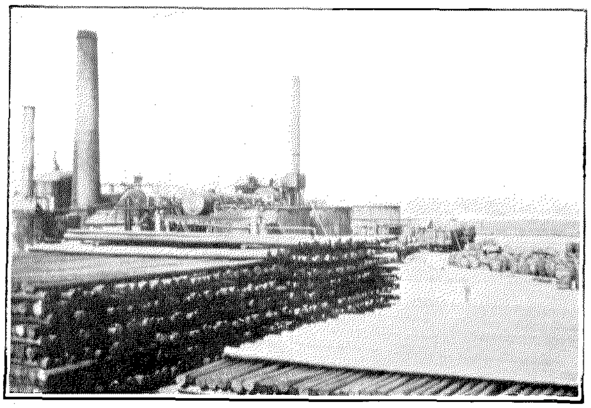


Figure 5—A Typical British Creosoting Plant.

Another process undergoing trial employs an aqueous solution of zinc and arsenic forced into the pores of the wood. The theory is that the zinc arsenite enters into solution with acids evolved by the fungus organisms and that the resulting compounds are destructive to the fungus. It is stated that the preservative will remain in the wood indefinitely and will not be leached out by the action of the weather.

Creosoting of Timber

Experience has taught that there is no better way of preserving timber than by the old established English method of pressure creosoting (Figure 5). The ever increasing demand for creosoted timber in England, on the Continent, and in America is the best proof of the value of the process.

Plant

Various modifications of the original Bethell Process have been in vogue during the past fifty years, but the type of pressure plant has mainly been the same (Figure 6). This plant consists essentially of the creosoting cylinder proper and a containing vessel mounted above it. Both of these cylinders are fitted with steam coils, and the lower cylinder is provided with a rail track which extends beyond the door on the trackage running from the stacks of timber in the creosoting yard. The upper and lower cylinders are connected together by means of large piping, so that the contents may be transferred quickly from one to the other. A water condenser is arranged in such a way that the lower cylinder may be connected to it and the whole kept under reduced pressure and at a temperature controlled by means of the steam coils in the cylinder itself. Creosote under pressure is supplied to either cylinder by means of a pressure pump, and compressed air or vacuum is supplied by another larger pressure pump. A control board is fitted with instruments which indicate steam pressure from the boiler, air pressure, vacuum, and creosote pressure within the creosoting cylinder. Recording thermometers are generally used, to give records of temperature during the whole cycle of operations. In practice it is convenient and advisable to have recording instruments for vacuum pressure as well as for temperature.

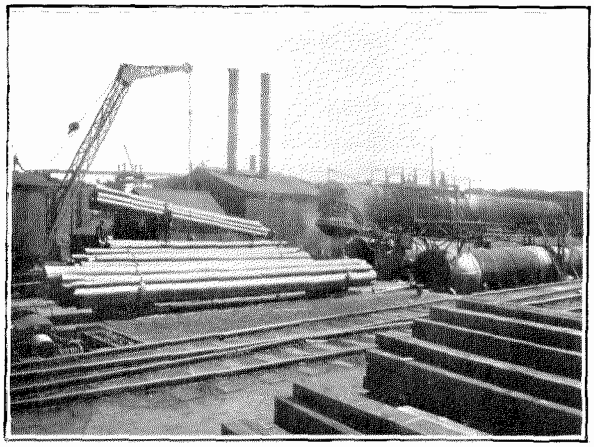


Figure 6—Creosoting Plant at Newport, Monmouthshire. (With acknowledgments to Messrs. Burt, Boulton and Haywood, Ltd., London.)

Impregnation

There are four main processes:

(*a*) *The Full Cell Process* (originally known as the Bethell Process), in which seasoned timber is fully impregnated with creosote by first exhausting air from the timber in the closed cylinder containing the timber, filling up the cylinder with hot creosote from the overhead container, forcing the creosote in by pressure until absorption is complete, and then emptying the cylinder and removing the timber fully charged with creosote.

(*b*) *The Boulton Process*, applicable specially to timbers for which no seasoning time is available. This consists in immersing the wet timber in a cylinder charged with hot creosote oil and applying vacuum. The oil must always be kept at a temperature above that at which water boils. The water vapour is condensed in the condenser placed between the creosoting cylinder and the vacuum pump. The temperature required is considerably below that at which injury occurs to the timber. Since the latter is always immersed in oil, there is no tendency to "shake."

As and when the water is removed, more oil is pumped in, and finally pressure is applied until the desired impregnation is reached. The cylinder is emptied and the charge removed.

(*c*) *The Rueping Process*, or that of full impregnation of sapwood and subsequent removal of oil. This process consists in first compressing air into the timber in a cylinder in which there is no oil. Above this cylinder, and suitably connected with it by pipes and valves, is a closed reservoir containing the oil. When the desired air pressure is reached, say four atmospheres, the oil is allowed to gravitate from the reservoir to the cylinder, whilst the compressed air takes its place in the reservoir. Pressure is then put on by force pumps until the desired quantity of oil has entered the timber. This pressure will be one or two atmospheres above normal air pressure. The pressure is then released, the oil removed from the cylinder, and vacuum applied. On first releasing the oil pressure, the compressed air imprisoned in the wood expands and expels a large quantity of the oil. The vacuum removes some more. Although the internal cells of the timber do not retain the full plugging of oil, they retain a coating of preservative. With this process it is possible to save at least 50 percent of the oil employed.

(*d*) *The Lowry Process.* The timber is placed in the creosoting cylinder, creosote is pumped in under pressure, and the pressure is maintained until the desired penetration has been effected. The oil is then pumped away and vacuum is applied to the cylinder until the excess creosote has been removed. This and analogous processes are largely used by the main railroads of the United States and Canada.

The custom of steaming wet or unseasoned timber before the admission of oil to the cylinder, formerly practised in Europe and very largely in America, has proved to be of no advantage in Europe. In America, the advisability of continuing its use is understood to be under investigation.

Perhaps the most interesting of the above mentioned processes is (*c*). It was introduced by Max Rueping of Charlottenburg in 1902, and is known as the "Empty Cell Method." The reasons for its adoption are:

(i) An economic reduction in the amount of creosote oil required.
(ii) The absorption of only so much liquid as is necessary to saturate the whole of that portion of the timber which can be permeated by the preserving liquid.
(iii) Oozing and sweating of wood is prevented and the timber, being dry and clean, it can be painted, if desired, after about three to six months standing.
(iv) Saving in cost without material reduction of the life of the poles so treated.

In practice there has been no occasion to replace certain poles which were impregnated by the Rueping Process in 1912.

In the Rueping Process it is customary to use seasoned timber as the general effect of this method is only apparent when the wood cells and pores are free from moisture. All kinds of combinations have been tried and it is quite possible that steam seasoning in conjunction with the Rueping Process may be utilised in some cases. If steam seasoning is used, vacuum must be applied after the steaming operation to assist vapourisation of the moisture in the timber.

The Rueping Process, as practised in England, begins with air pressure, as initial vacuum would not produce any beneficial result. The air pressure usually is raised to about 4 atmospheres above normal. The temperature of the creosote is from 150 to 180 degrees Fahrenheit. The creosote pressure may be anything from 80 to 200 lbs. per square inch according to the nature of the timber. After release and removal of the creosote from the cylinder, the final vacuum usually is drawn to about 26 inches. The oil remaining in the timber will vary according to the kind and condition of the wood at the time of treatment, and to the amount of oil put in under the maximum pressure. In the case of European poles of *Pinus Sylvestris*, it is customary to inject a maximum amount of oil—equal to about 12 lbs. per cubic foot—and to leave in the timber about 5 lbs. per cubic foot.

In all timber there is a possibility of some portion of the wood being drier or more seasoned than others. This condition is largely immaterial when the pole is creosoted by the Full Cell Process, but in the case of the Rueping method, unseasoned portions of wood may not be completely impregnated, since the initial air pressure prevents the release of moisture, and the interior cell walls in these parts do not therefore get their due proportion of oil.

In the case of the Lowry Process, which resembles the Rueping Process but which does not employ air pressure above normal, the return of oil from the timber is less than with the Rueping Process. With the older processes, the aim usually was to inject into the wood as much oil as possible and for that reason the oil was let into the cylinder under a vacuum. The Boulton Process, which falls into this category, provides a means of removing the moisture from damp timber without prolonged stacking. If applied to the limit, as much as 20 to 30 lbs. of oil per cubic foot can be left in the timber.

With the Rueping Process there is not the same quantity of creosote left in the timber as with the Full Cell treatment, and as all timber "cracks" when exposed, the empty cells become exposed and are then subject to decay. With a fully creosoted pole there is not the same probability of "cracking," as all cells are filled. Moreover, the flow of creosote down the pole tends to fill in cells which may be exposed, due to "cracks." It also saturates the surrounding soil, checks decay at the ground line, and thus aids in lengthening the life of the pole.

In summarising in general terms the various available methods of creosoting pole timber, it may be stated that the Empty Cell Process has the advantage that the quantity of creosote consumed is a minimum, also that poles so impregnated may be painted after a short standing period and Ruepingised poles do not ooze or sweat so as to cause damage to property or clothing. The Full Cell Process, on the other hand, affords the greatest assurance of maximum length of life of the poles.

Thermionic Vacuum Tubes

By L. H. BEDFORD

Engineering Department, Standard Telephones and Cables, Ltd.

and W. T. GIBSON

European Engineering Department, International Standard Electric Corporation

THE thermionic vacuum tube now has a sufficient diversity of uses in communication engineering to justify a description of the various types available as well as of the methods employed in its manufacture.

The history of the vacuum tube as an instrument of value to the communication engineer dates from Professor J. A. Fleming's production in 1905 of the two-electrode "valve" which consisted of a filament and an anode mounted in a vacuum. When heated, the filament emitted electrons which could be collected by the anode. This tube was of use only as a rectifier. The next great step was made in 1907 by de Forest, who introduced a third electrode between the filament and the anode for controlling the anode current. It undoubtedly was the precursor of the modern vacuum tube, but development was very slow in the early years, largely because of the difficulty experienced in procuring and maintaining a suitably high vacuum. The development of the modern high vacuum tube dates from 1912. At this time the American Telephone and Telegraph Company, and the Western Electric Company were carrying out research work on telephone repeaters and had recognised that the vacuum tube amplifier would become a very valuable instrument provided it could be made stable in action, and with long life.

High vacuum technique had been developed to a high point as a laboratory art by Professor Dewar and numerous others. Although these methods were not being practised in ordinary glass-working establishments, as soon as the necessity for obtaining and maintaining an exceptionally high vacuum was thoroughly appreciated, they were adapted to factory procedure and a high vacuum product became quickly available.

Having obtained the high vacuum by methods which will be described at more length in what follows, attention was turned to the development of a suitable source of electrons.

The filament desired is required to meet two conditions: (*a*) long life and (*b*) high thermionic efficiency, that is, high electron emission per watt of heating power. These requirements, however, are invariably conflicting, for the relation between emission and temperature is such that increase of temperature gives increased thermionic efficiency, while at the same time the rate of evaporation of the emitting material is increased, with consequent reduction of life. Compromise, therefore, is necessary.

The actual relation between emission and temperature is given by Richardson's equation:

$$i = AT^{1/2}e^{-b/T},$$

where i is the electron emission current,

T is the absolute temperature,

A and b are constants.

In studying the economy of operation of filaments, it is generally of greater importance, however, to consider the relation between i and the power w expended in maintaining the filament at temperature T. C. J. Davisson, of the Bell Telephone Laboratories, Inc., has devised a system of coordinates such that when w and i are plotted as abscissæ and ordinates, the power emission curve for the surface appears as a straight line on the chart, provided, however, that the material obeys the Richardson equation and that the power radiated is proportional to the fourth power of the temperature in accordance with the Stefan Boltzmann law. By means of this chart, the study of filaments is facilitated very considerably.

Among the chief materials available for filaments at the time the investigation was started were tantalum and tungsten. The constants, A and b, of these materials are such that unless the filaments are run at exceedingly high temperatures the emission is negligible. The efficiency is low and for tungsten at ordinary operating temperature, for example, may be of the order of 5 milliamperes per watt of heating

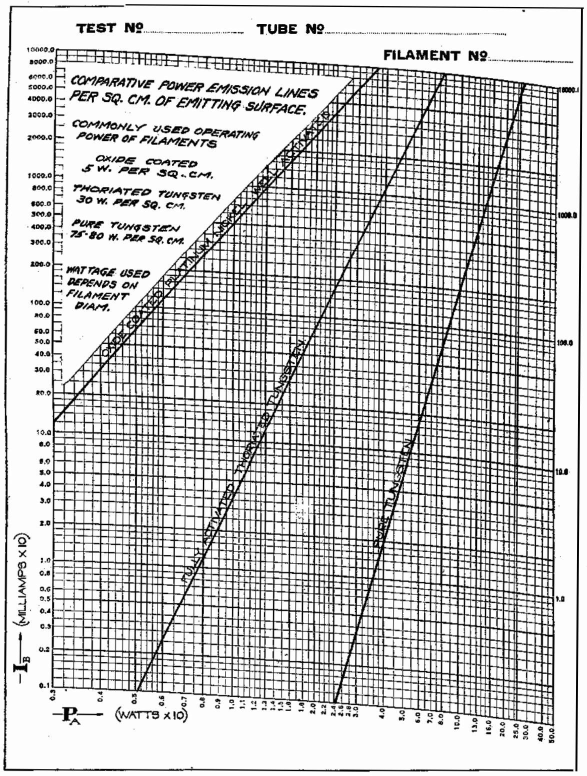


Figure 1—Power-Emission Lines for Tungsten, Thoriated Tungsten and Oxide Coated Filaments.

power. At lower temperatures the efficiency is too low to be of any interest in the production of vacuum tubes for use in communication engineering. Moreover, at the temperature at which emission begins to be of useful magnitude the material is not very far below its melting point and the vapour pressure is so high that evaporation proceeds fairly rapidly with the result that the filament life is short. In the case of tantalum, similar statements apply. Furthermore, previous to failure by burning out, there is nothing to indicate that the end is near, inasmuch as the whole filament is so bright that any local temperature inequality cannot be discerned. The possibility of tube failure without warning is in itself a very serious disadvantage in a communication line, and alone practically rules out the use of these metals except for power tubes employing high anode voltages.

In 1905, Wehnelt had described a cathode commonly known as the "lime cathode," which was a very efficient electron emitter at relatively low temperatures. It consisted of a strip of platinum on which was placed a speck of lime. It had comparatively high efficiency and operated at a very low temperature, so that the vapour pressure was low, and the life might be made long. In addition, the temperature was so low that any local brightness variation preceding failure was easily visible. The life of the filament was, however, short on account of the coating material breaking loose from the metallic core, and falling off. The Western Electric engineers recognised that this filament had the properties they were looking for except

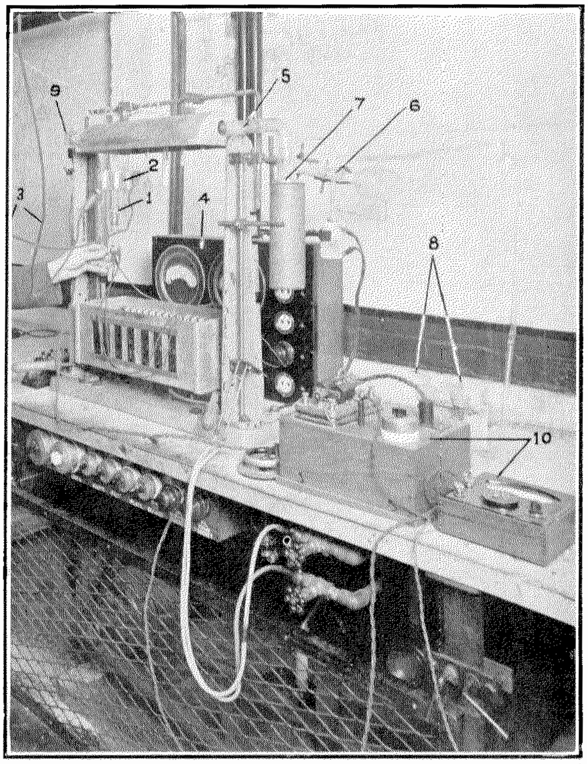


Figure 2—A No. 4211-D Tube under High Frequency "Gettering"; the last stage in the exhaust process. (1) 4211-D tube; (2) High Frequency Coil; (3) High Frequency Leads; (4) Bombarding Panel; (5) Header; (6) Mercury Aspirator; (7) Liquid Air Trap; (8) Mercury-sealed Cocks to Oil Pump System; (9) Ionisation Manometer Tube; (10) Ionisation Manometer Set (Hendon Valve Laboratory).

that the life was too short and uncertain, and they concentrated their efforts on improving it. The results of the work led to the production of a very active coated filament of uniform activity throughout its length, operating at a dull red heat, and having exceedingly long life so that it is now possible to make filaments having an efficiency roughly of 200 milliamperes per watt, and having a life of 25,000 to 50,000 hours or more. Furthermore, this type of filament, before burning out, gives considerable warning of failure, by the formation of bright spots upon it, so that it can be removed at leisure with no danger of interruption of service. It is also comparatively free from objectionable rustling noises which are heard in circuits of high amplification when tungsten filament tubes are used.

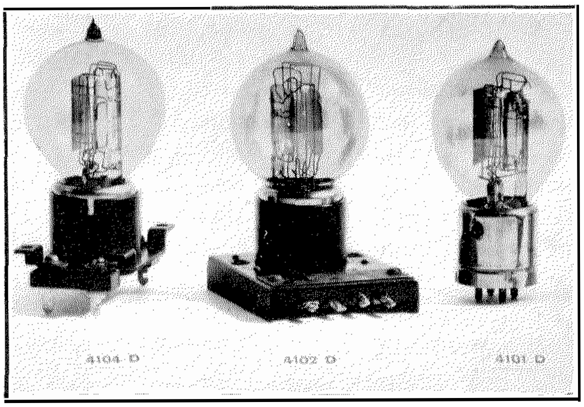


Figure 3—The Repeater Group.

Figure 1 shows comparative power-emission lines on the Davisson Chart for oxide coated as well as for tungsten filaments. A line for thoriated tungsten, another extensively used dull emitting filament, also is shown.

The method of manufacture of the modern oxide coated filament is essentially as follows: a wire or ribbon core of an alloy of platinum and nickel with a very low vapour pressure at the operating temperature is used. It is coated by applying a large number of thin layers of a compound of barium and strontium. After the application of each layer, the filament is heated in air to a high temperature to cause chemical combination of the materials with the core, and at the conclusion of the coating process the material is baked for some time to ensure its adhering firmly and not falling off while the tube is in service.

During the process of heating each layer, the compounds decompose first into barium and strontium oxides which then combine with the core-metals and oxygen, forming stable compounds. In this state the filament may be stored for future use. During the evacuation of the tube the filament is heated, and a reverse action occurs; oxygen is evolved and barium and strontium oxides are left very finely divided upon the surface.

The original filament was made in a similar way but had a core of platinum. The use of the alloy led to a very considerable increase in activity and life, and made possible a reduction in operating filament current. Continual development of details of technique of manufacture has led to increased activity and life, and at the same time has ensured a more robust product, so that the modern material can give high emissions and can be used with high anode voltages.

The processes involved in manufacturing this type of vacuum tube have been the subject of considerable investigation by Western Electric and International Standard Electric engineers, with the result that the details are now well understood, and the essential factors are kept under constant control in the factory. This supervision applies not only to all stages of manufacture, but also to the inspection and testing of all raw materials.

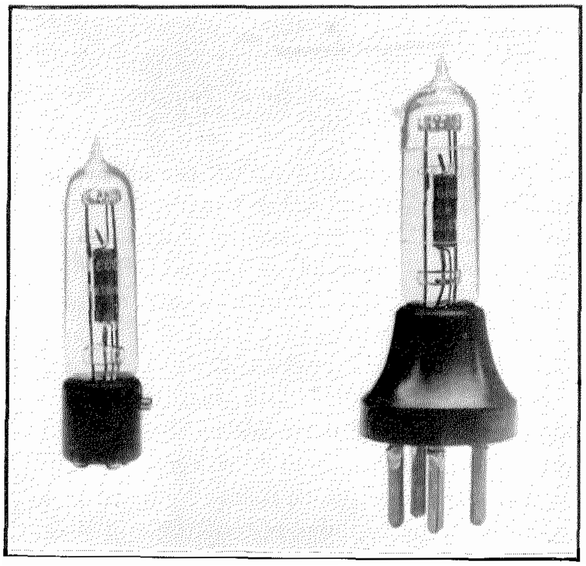


Figure 4—The Peanut Types G.125 and G.125-A.

In the manufacture of telephone repeater tubes, radio receiving and low power transmitting tubes, the same general methods of manufacture are followed. A point of the greatest importance throughout is absolute cleanliness—chemical cleanliness. All glass, for instance, must be cleaned specially and all metal that is to be located in a vacuum must be cleaned and denuded of gas before use by heating to very high temperature in a vacuum electric furnace.

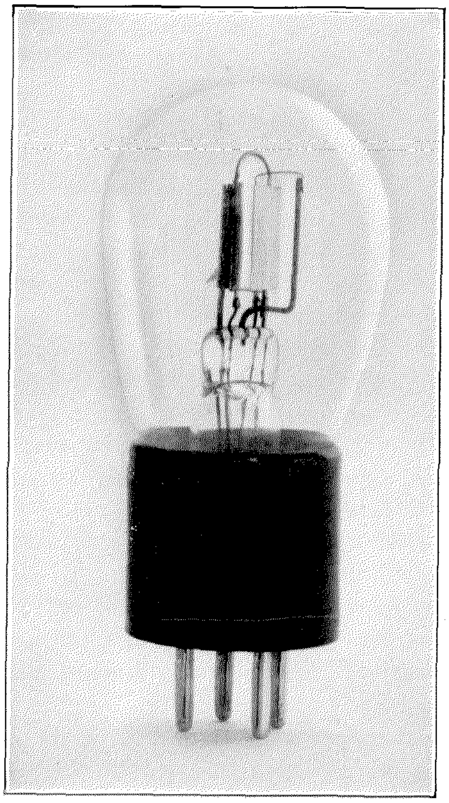


Figure 5—The G.225 Tube. (Magnesium Getter omitted for clearness.)

The parts are assembled by skilled workers, or by machines, and are located accurately in the required positions by electro-welding while they are held in jigs. The metal parts when correctly aligned and mounted upon their glass supports are sealed into the glass bulb, usually by machine, and the bulb is provided with a tube through which it may be exhausted. This tube in the case of the "tipless type" of vacuum tube, is sealed into the same end of the bulb as the supporting stem and is hidden in the finished product by being covered by the base.

The bulb is sealed by fusion on to the glass header of an exhaust station. A typical exhaust station layout is shown in Figure 2. Under the bench are located the necessary rotary oil pumps for producing a "fore" vacuum in the bulb of the Mercury Aspirator (6), the pressure here being of the order of 0.001 mm. of mercury. The Aspirator produces a high vacuum in the header (5) by entraining the gas molecules in a high speed mercury vapour stream flowing from the nozzle to the condensation bulb. To prevent mercury vapour diffusing back into the header, a liquid air trap (7) is provided. The bulbs to be exhausted are so placed that an electric oven can be closed round them, and connections made

TABLE

Group	Code No.	Filament Volts	Filament Amperes	Plate Volts	Amplification Factor	Impedance Ohms	Output as Oscillator
Repeater Valves.......	4101-D	4.4	0.97	130	5.9	6000	—
	4102-D	2.0	0.97	130	30	60000	—
	4104-D	4.4	0.97	130	2.4	2000	1.5 watts
Radio Receiving Valves.	G-125	1.0	0.25	45 to 60	6.0	25000	—
	H-125	1.0	0.25	45 to 90	11.4	45000	—
	G-225	2.0	0.25	120	8.5	17000	—
	P-425	4.0	0.25	130	6.6	6000	—
	P-612	6.0	0.12	130	6.0	6000	—
Radio Transmitting Valves (Radiation Cooled)............	4205-D	4.4	1.6	250 to 350	7.0	3500	5 watts
	ES 755-1	8.0	1.6	500 to 750	8.5	3200	20 watts
	4211-D	10.0	3.0	750 to 1000	12.0	3000	50 watts
	4212-D	14.0	6.0	1500	16.0	2000	250 watts
Water-cooled Valves....	4228-A	22	41	4000	16	—	4 KW.
	4220-B	22	41	10000	40	—	10 KW.
	SS-1916-1	22	41	17000	40	—	20 KW.
	4222-A	22	41	—	—	—	—

Notes: (1) The plate voltages listed in this Table are normal or normal to maximum.

(2) Figures given for the water-cooled valves are subject to considerable modification according to the condition of use.

to the electrodes at the same time. The exhausting schedule is in general similar for all tubes employing these oxide coated filaments. The glass is first heated, with vacuum pumps

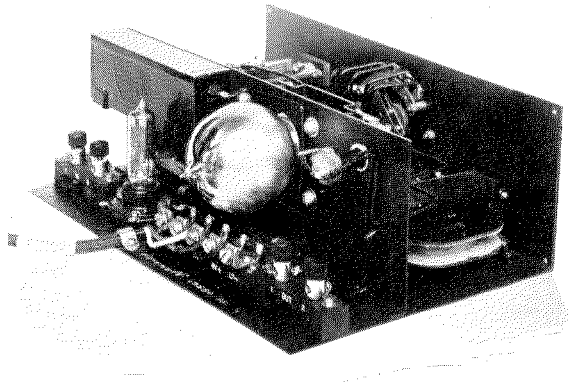


Figure 6A—The P.425-A Tube, shown in center of Kone Amplifier for which it was primarily developed.

working, to just below its softening temperature, to denude it of gas. The filament then is subjected to a "breaking down" process in which the compounds of coating and core-metal are decomposed by heat. This step is followed by processes of filament activation, by means of which the thermionic efficiency is increased to the desired value, and by very intensive electronic bombardment of grid and anode. By making the grid and anode positive and drawing emission current to them from the filament, sufficient power is dissipated in these elements to raise them to a very bright red heat, which causes rapid evolution of gas. By this process the parts are raised to a much higher temperature than they will attain in service, and are held there until the gas is thoroughly pumped out. When the parts afterwards reach normal temperature, the pressure falls to an exceedingly low value.

In some types of tubes, a "getter" or small disc of magnesium metal is used. It may be vapourised and deposited as a silvery mirror on the glass of the bulb through the agency of heat conducted and radiated to it by the anode, which is heated by electronic bombardment. This process is useful in obtaining the final stage of high vacuum, inasmuch as gas is picked up by the magnesium in its passage to the walls of the bulb and is held there firmly by physical and chemical forces.

When the exhaust process has been carried to the desired degree, and the required filament efficiency is obtained, the bulb is sealed from the pumping equipment by carefully heating the constricted tubing and allowing the glass walls to fall in until they unite. In this process it is most essential that the heating be carried out in a manner such that gas is not liberated from the hot glass into the bulb.

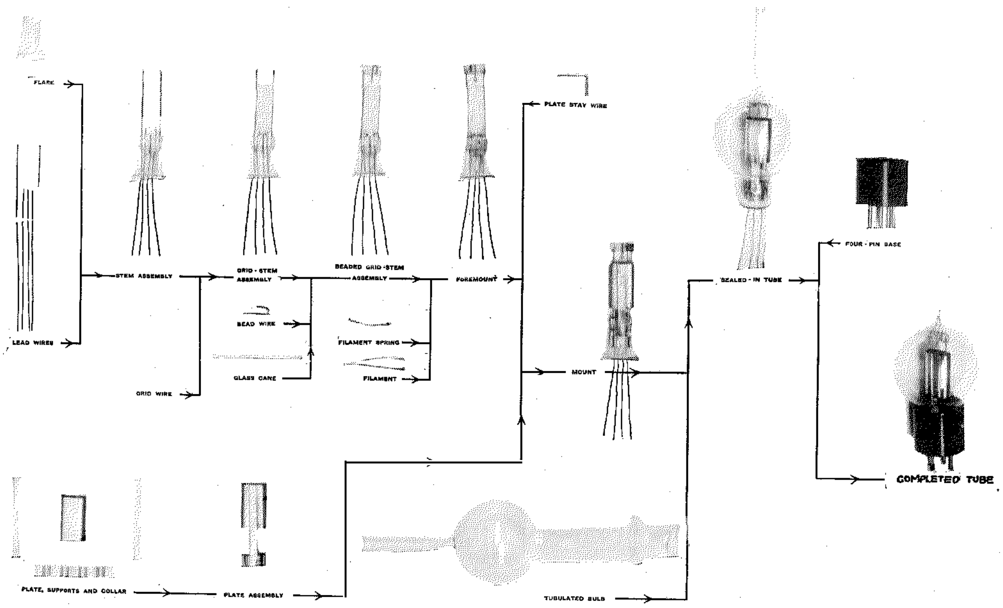


Figure 6B—A Development View of the P.425 Tube (with magnesium omitted).

After the tubes are removed from the pumps they are put through an "aging" process with a view to stabilising the thermionic efficiency of the filament, and they then are subjected to

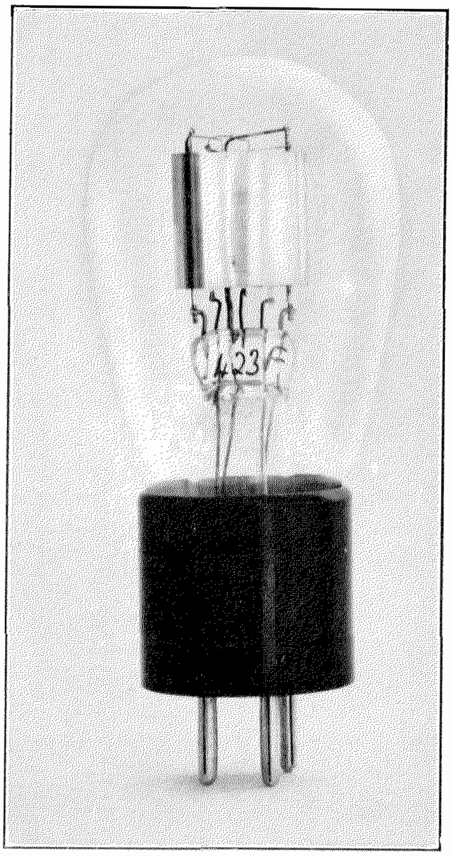


Figure 7—The P.612 Tube. (Magnesium getter omitted for clearness.)

very searching tests framed to ensure the qualities desired for communication purposes.

Repeater tubes are placed in a test circuit which measures directly the power amplification or gain which they will give in a typical repeater circuit. The gain is measured not only at the normal filament current, but also at a current about 10 per cent below normal. The latter shows the working of the filament at "temperature saturation," a very important factor in the easy maintenance of long repeatered circuits. Measurements of plate impedance, insulation resistance and gas pressure also are made.

The foregoing, in general, is the manufacturing procedure in the case of all vacuum tubes employing the oxide coated filament.

Tubes manufactured by Standard Telephones and Cables, Ltd., may be divided into different groups according to their uses, as follows:

(1) *The Repeater Group.*—(See Table and Figure 3.) This group consists of the 4101-D, 4102-D and 4104-D vacuum tubes. These are all of similar appearance but have electrical characteristics suiting them to different uses in the telephone plant. Thus the 4102-D is of rather high impedance with high μ, and is used largely for the first stage; i.e., the voltage amplifier stage of 4-wire repeaters. The 4101-D is of medium impedance, and medium μ and is used in 2-wire repeaters and in the output stage of 4-wire repeaters. The 4104-D is of low impedance and low μ and is used in certain transmission measuring apparatus and in carrier telephony.

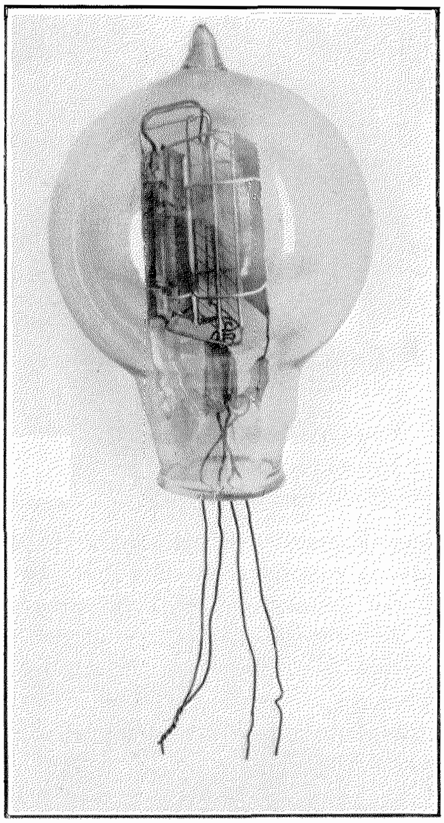


Figure 8—An Unbased 4205-D Tube, showing the long insulation path provided for the platinum lead. In other respects, the structure is identical with that of the repeater group of tubes.

(2) *The Radio Receiving Group.*—(See Table and Figures 4 to 7 inclusive.) This group consists of a series of tubes having lower filament

consumption, and characteristics suited to the different stages in radio receivers. They are the G-125, H-125, G-225, P-425 and P-612.

The nomenclature used in this group indicates to some extent the type of tube; viz.,

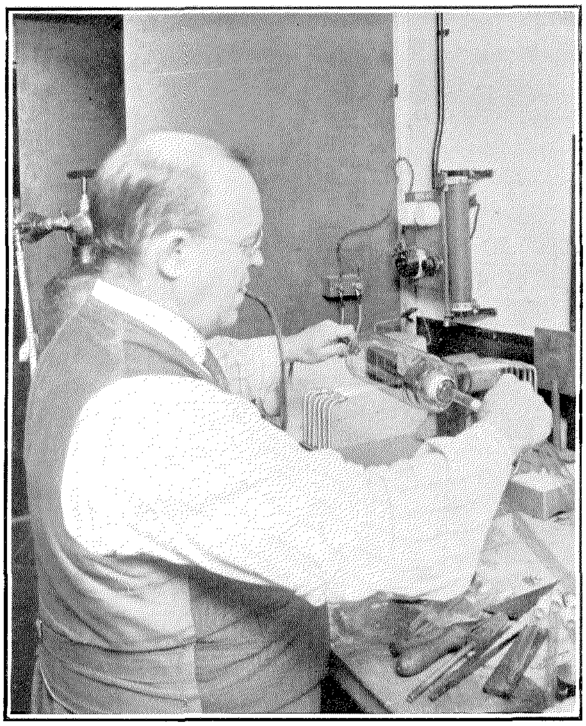


Figure 9—A 4212-D Tube in the Sealing-in Process. (Hendon Valve Laboratory.)

G—General purposes,
H—High frequency amplifier,
P—Power amplifier.

The three figures following the letter indicate the filament consumption, the first one giving the filament voltage and the succeeding two the filament current in hundredths of an ampere. Thus the P-612 is a power amplifier tube suitable for the last audio frequency stage. It operates with a filament voltage of 6, and with a filament current of 0.12 ampere.

With the exception of the 1-volt tubes the other members of the group are designed for direct operation from the accumulator supply without the use of rheostats. Such an operating arrangement is made practicable economically by the latest oxide coated filament and requires that emission be adequate until the accumulator is effectively discharged, and that the filament be not overloaded by a newly charged battery.

(3) *The Radio Transmitting Group.*—(See Table and Figures 2, 8, 9, 10 and 11.) This group may be subdivided according to the power rating of the tubes:

	Code Number
5 watt	4205-D
20 watt	ES-755-1
50 watt	4211-D
250 watt	4212-D

In order to reduce the operating temperature of the anodes or plates of the 50 and 250 watt tubes, they are made of black oxidised nickel, as this surface has a much higher thermal emissivity than bright metal.

(4) *The Water-cooled Group.*—An entirely different group of tubes in which oxide coated filament cannot be used is that distinguished as the "water-cooled" group (see Figures 12 and 13) and is used where large quantities of energy are handled, such as in the case of the Rugby Station.[1] It includes:

4-KW. tube—Type 4228-A
10-KW. tube—Type 4220-B

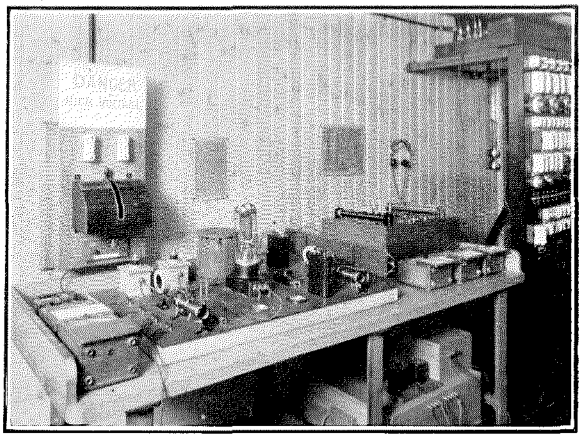


Figure 10—A 4212-D Tube on the Oscillation Test. The circuit is of the Colpitts type and is used for testing both 4212-D and 4211-D type tubes, and also for supplying the high frequency current for the gettering process (Figure 2). In the background is a receiving tube test set.

and the special 20-KW. high voltage tube SS-1916-1. Suitable rectifiers are provided to supply anode voltage to these amplifiers.

The important difference between these tubes

[1] "Transatlantic Radio Telephony-Radio Station of the British Post Office at Rugby," E. M. Deloraine, ELECTRICAL COMMUNICATION, Vol. 5, No. 1, July, 1926.

and those previously discussed is that the anode forms part of the external wall of the tube. As the anode is of copper, which may be water-cooled, the greatest problem of high power tube design—that of getting rid of the power dissipated in the anode—is easily overcome. This design was made possible through the invention by Houskeeper, of the Bell Telephone Laboratories, Inc., of a means of making vacuum tight seals between metals and glasses having different temperature coefficients of expansion. The sealing process is accomplished by reducing the edge of the metal tube to a fine taper and at the same time making it very thin. The result, if the reduction is correctly made, is that the metal will yield to the expansion and contraction of the glass, and the joint will withstand temperature changes without any danger of cracking. Using this method, the 10-KW. anode is made of drawn copper, two inches in diameter, sealed directly at its open end to a glass envelope which serves to support and insulate the grid and filament assemblies, which are mounted within the anode. The grid and filament structures are designed specially to allow heating to very high temperatures during exhaust, and consequently are constructed of molybdenum, while the filament itself is of tungsten.

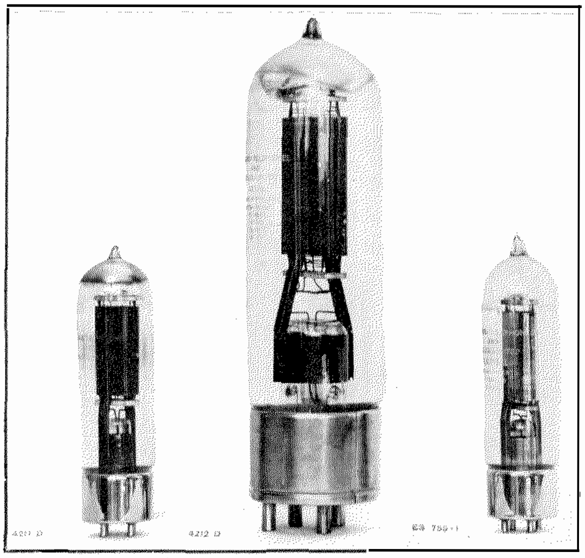


Figure 11—The 4211-D, 4212-D and ES-755-1 Tubes.

Just below the thin taper, which is sealed to the glass, a rim is provided all round the anode. When the tube is in use, this rim is clamped by means of a ring to a seat provided in the top of a metal water jacket. Electrical connection to the anode is made by connections to the water jacket. In the general method of use, the anode is at a high positive potential, say 10,000 volts, and water is supplied from a tank at earth potential through a rubber hose. By suitably choosing the hose dimensions, the conductance of the water column can be arranged to introduce negligible electrical loss.

These tubes are provided with pure tungsten filaments and necessarily consume considerable power in the filament, which contains sufficient material to ensure adequate electronic emission for very high peak values.

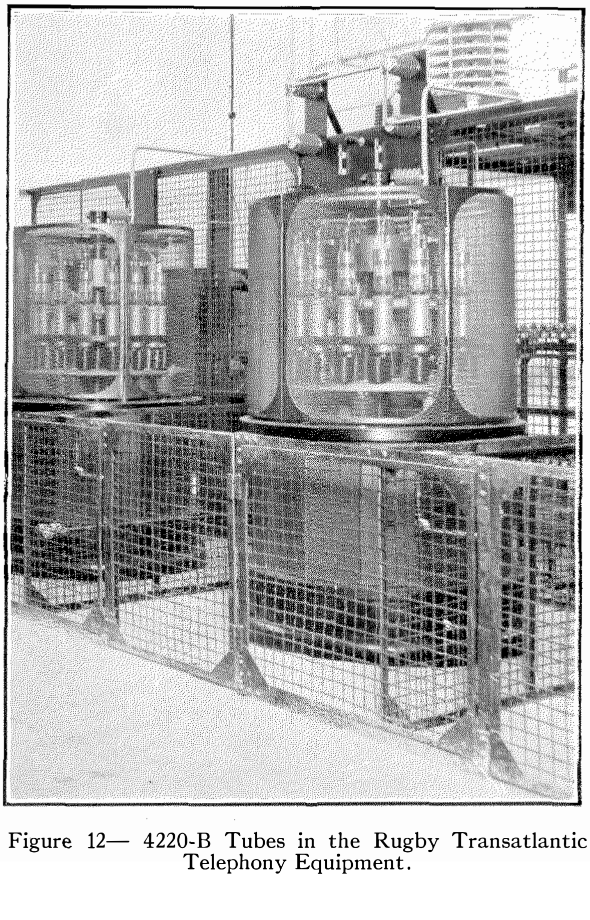


Figure 12— 4220-B Tubes in the Rugby Transatlantic Telephony Equipment.

Ordinary lead glass tubes have been designed to operate up to 12,000 volts. The special type SS-1916-1, 20-KW. tube, however, contains a

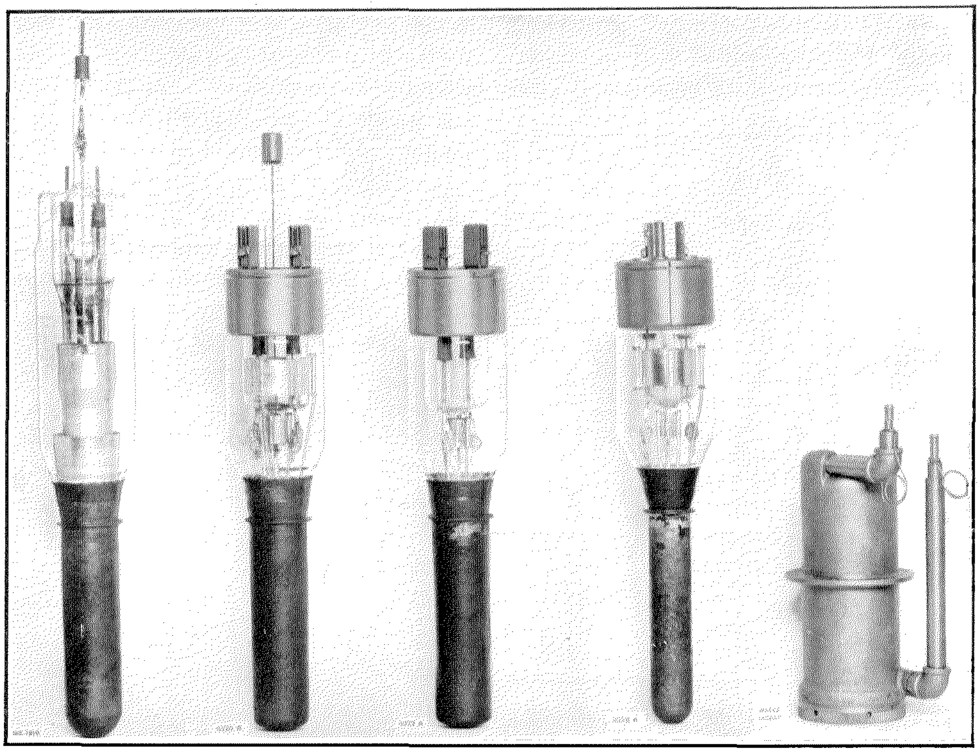


Figure 13—The Water-cooled Group.

Pyrex glass construction which makes possible the use of much higher voltages. This type can be operated with rectifier supply for the anode voltage at 17,000 volts.

The Gamewell Fire Alarm System

By L. H. WEBB

Engineering Department, Standard Telephones and Cables, Ltd.

THE development of the modern Fire Alarm System has paralleled and kept pace with that of large urban areas. With the growth of a town, property value and density of population increase very rapidly. It becomes vitally necessary, under such circumstances, to provide means of summoning the Fire Brigade immediately an outbreak of fire is discovered.

Experience has shown that prompt attention at the commencement of an outbreak is an important element in limiting the area affected and the loss sustained, whereas even short delays at this period may permit a fire to get a firm hold with consequent loss of life and property. The alarm equipment, therefore, must give immediate indication of the locality in which the fire has occurred and the indication must be fully automatic. Furthermore, a high degree of skill or intelligence in sending in the alarm signal or in reading the alarm indication at the Fire Station must not be necessary.

The design of the equipment, in addition, must be such that it can remain idle for months without risk of failure when required and give instant indication of any derangement which would prevent the correct transmission of the signal.

Modern Fire Alarm Systems usually employ telegraphic code signals and fall into two main classes.

1. Open circuit systems
2. Closed circuit systems

In open circuit systems the signal is sent by closing an electrical circuit and permitting the current to flow through the signaling apparatus. Such a system suffers from the very serious disadvantage that no indication is given when the circuit is disconnected by a fault, and the alarm box may be inoperative without any indication of the fact being given.

In closed circuit systems the current flows continuously, the alarm boxes being connected in series, and the signal is given by the opening of the electrical circuit. Should a disconnection occur it is, therefore, immediately indicated by the signaling apparatus at the Fire Station. This is known as the self-testing feature, and provides continuous supervision of the entire system.

The Gamewell Fire Alarm System

The Gamewell Fire Alarm System was one of the earliest practical systems and is based upon the closed circuit principle. The general arrangement of the System may be described as follows:

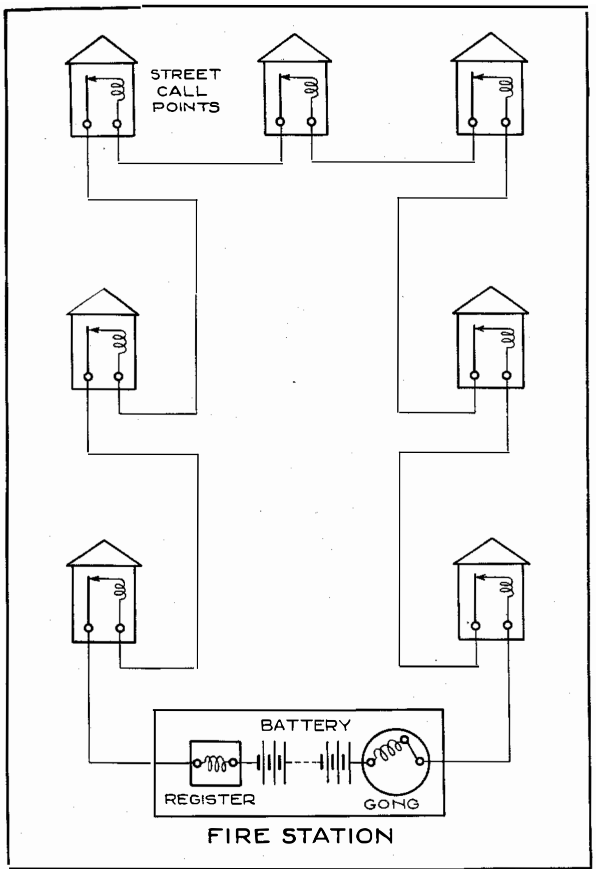


Figure 1—Gamewell Closed-circuit Loop, illustrating connections of street boxes and station apparatus.

The street boxes, as illustrated in Figure 1, are arranged at intervals on a single wire electrical circuit in series with the Fire Station signaling apparatus and a central battery located at the Fire Station. A continuous current of 100 milliamperes is maintained in this circuit, and any interruption thereof causes the Fire Station apparatus to operate immediately.

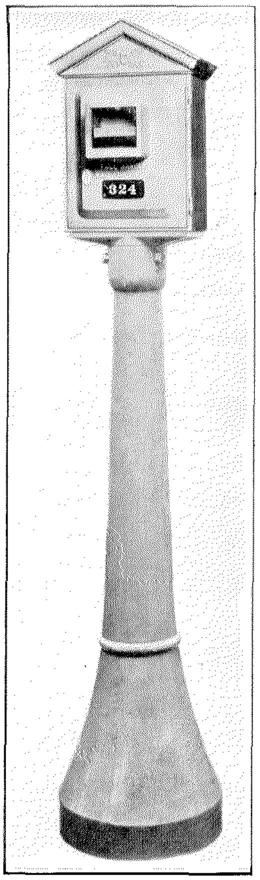


Figure 2—Succession Non-interfering Box with Mounting Post.

When a street box is operated, an electrical circuit is interrupted a certain number of times in accordance with a code number allotted to the box, and the alarm is received at the Fire Station on a gong and a register. The gong repeats the number of the operated street box in a loud resonant tone, which can be heard all over the Fire Station and which directs immediate attention to the alarm and the location of the box sending it. The register makes a permanent record on a paper tape of the number of the box from which the alarm originated.

The paper tape, which is paid out by the register, is collected automatically by a take-up reel and, if required, a time stamp can be added which automatically stamps the tape with the full time and date at which the alarm was received. The arrangements are such that the number of the box is sent twice in succession so that no mistake may occur, and the full code, stamped with the date and time, is left exposed to view on the register tape when the register stops.

The fact that all street boxes are connected together in series gives rise to the possibility of interference if more than two boxes are operated together. To avoid this possibility, and the consequent muddled effect which would be produced at the Fire Station, non-interfering devices may be introduced into the box, in which case succession features usually are added as well. Thus, street boxes fall under two main headings: (1) The plain box, viz., one unequipped with non-interfering devices or succession features, for use in areas where the fire risk is so small that the chance of two boxes being pulled together is negligible; (2) a non-interfering, succession type box which is not only non-interfering with regard to a neighbour box pulled at the same time, but which is also successive in that it will transmit its call to the Fire Station when the other box has left the line free. The non-interfering succession box is favoured in densely populated areas where the risk of two calls being originated on any one circuit at the same time exists.

The movements of the street boxes and Fire Station apparatus are operated electromechanically, powerful main springs being employed to drive the mechanisms with electromagnets to control them in nearly all cases. Ample reserve power is, therefore, always available, and the mechanisms can be made sturdy and consequently reliable in operation.

The electrical portion of the apparatus in the street boxes is mounted on porcelain throughout in order to maintain the highest possible insulation under all circumstances.

In order to secure adequate protection against the most severe weather conditions, the movement of the street boxes is housed in a triple cased iron box. Each case is practically dust tight; and air spaces, which have the effect of reducing to a minimum any likely changes of temperature in the case containing the movement, are provided between the cases. Thus, the deposition of moisture and all the resultant troubles due to corrosion are prevented.

Street Boxes

The outside of the box which houses the non-interfering mechanism is shown in Figure 2. The pull handle is normally covered by a sheet of glass which it is necessary to break before an alarm can be given. In so doing, a frame which carries the sheet of glass is thrown forward under the action of a spring in such a manner as to clear the glass from the vicinity of the pull handle, and so reduce the risk of cut hands due to splintered glass. It is then only necessary

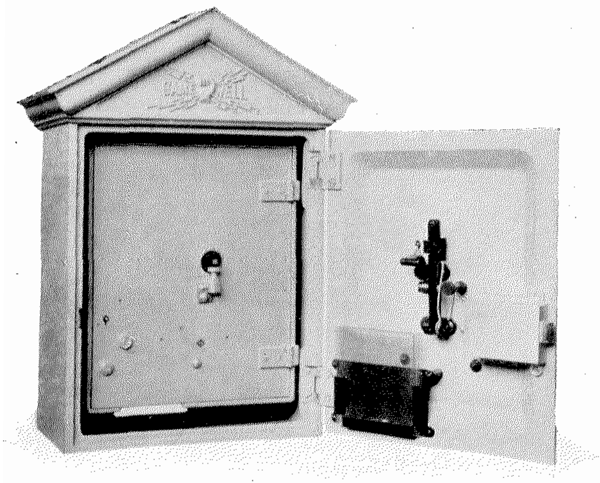


Figure 3—Succession Non-interfering Box with Outer Box Door Open.

to pull the handle forward in order to set the mechanism in operation. Figure 3 shows the door of the outer box open and, on the inside of this door, the lever mechanism which transfers the pull to the inside box. This inside box houses the third and innermost case containing the signaling mechanism and also testing and communicating apparatus for talking or sending telegraph messages to the Fire Station (Figure 4).

A plunger type key is provided for throwing additional resistance into the circuit in such a way that the mechanism can be tested without interfering with the other boxes on the circuit or the station recording apparatus. When the door is closed, the plunger type key and the additional resistance referred to are short-circuited. A lightning protector is provided to protect the apparatus from high potential currents.

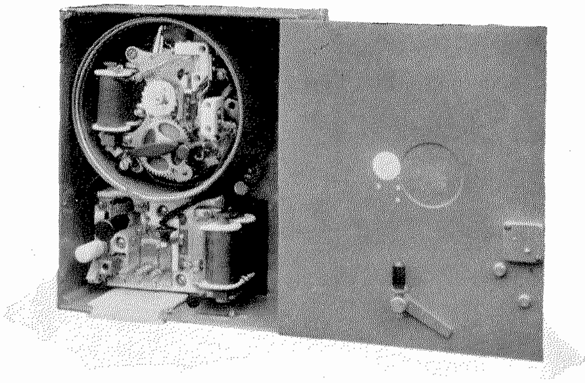


Figure 4—Inside Box of Succession Fire Alarm Box.

The Succession Movement detached from its case is shown in Figure 5. When the starting lever is depressed in response to a pull from the outside of the box, the wheel train starts to revolve and carries round the code wheel in the centre of the movement. If at the time there is no other box sending an alarm signal, the electromagnet will hold its armature and the code on the teeth of the signal wheel will be transmitted to the impulse springs in such a manner as to make and break the line circuit in accordance with the code of the box. This

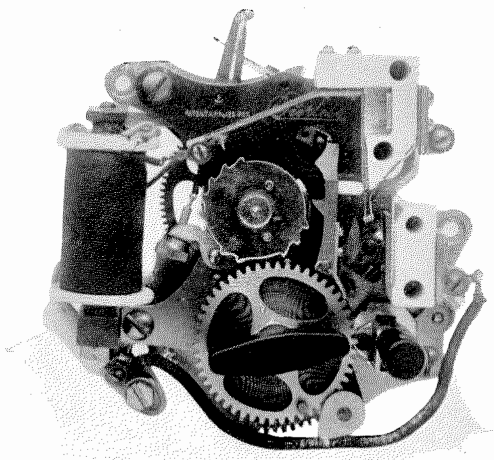


Figure 5—Succession Non-interfering Box Movement.

signal is given twice, after which the wheel train is brought to rest and a pair of heavy springs are brought together to make electrical contact in such a way as to bridge the signaling contacts and the electromagnet which are

Figure 6—Plain Type of Box.

themselves connected in series. This shunting switch completely short circuits the movement coils when the box is idle. If, however, another box is signaling an alarm when the box under

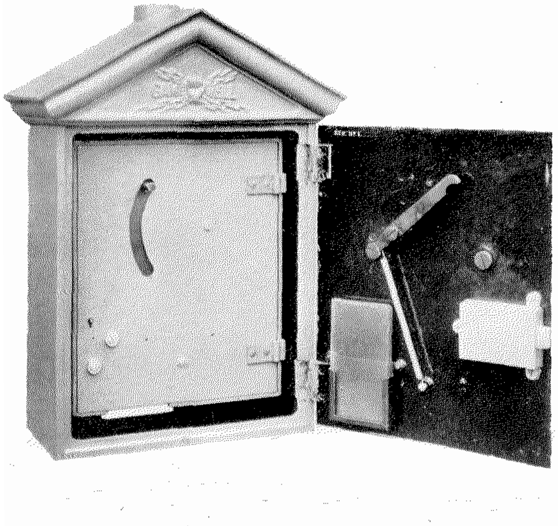


Figure 7—Plain Type of Box. Outer box door open, showing inner box.

consideration is pulled, the electromagnet releases its armature on account of the intermittent line current and the signaling contacts are locked in the closed position in order not to break the series circuit of the other box signaling. In this case the wheel train continues to rotate, but idly, so that no signals are transmitted, neither does the box get any nearer its position for shutting down. At each revolution of the code wheel the armature is forced up mechanically to the pole face of the electromagnet, and if on any one of these occasions the line is disengaged, the armature will be held to the cores and the normal transmission of the signals will commence. After two effective revolutions of this wheel, the mechanism shuts down and is restored to normal.

The plain street box is illustrated in Figures 6, 7 and 8. It operates on a similar general principle to the succession box, but has no non-interfering apparatus to provide for the case when more than two alarms are sent in at the same time and on the same circuit. The box is

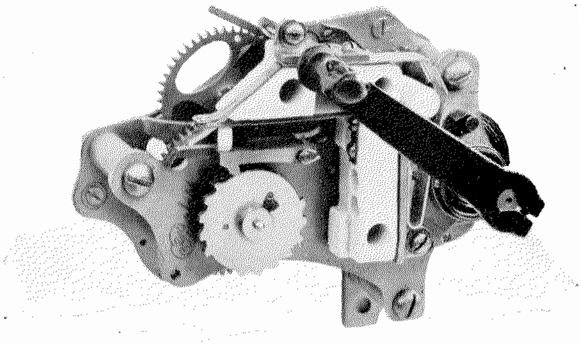


Figure 8—Movement of Plain Type of Box.

operated by means of an arm connected to the shaft on which the main spring is anchored. To send in an alarm, it is necessary to break the glass in the outer door and to pull down the lever, thereby winding up the main spring which drives the clockwork mechanism and rotates the code wheel on the return stroke. The design of the mechanism is such that it is not possible for a succession of pulls on the part of a person giving an alarm to interfere with the rotating mechanism. The testing and connecting apparatus in this box are exactly similar to that of the succession box.

Fire Station Apparatus

The Register

To record fire calls from one circuit only, the single circuit register, illustrated in Figure 9, is used and is connected directly in the box circuit. It punches a ¼ inch hole in the tape every time

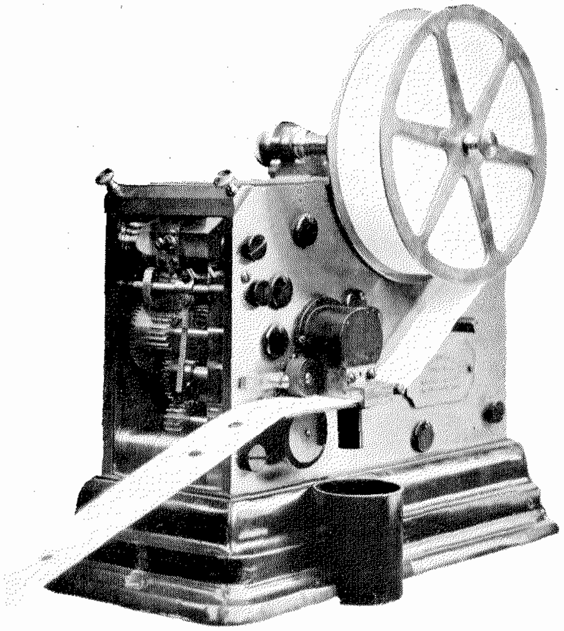


Figure 9—Single Circuit Register.

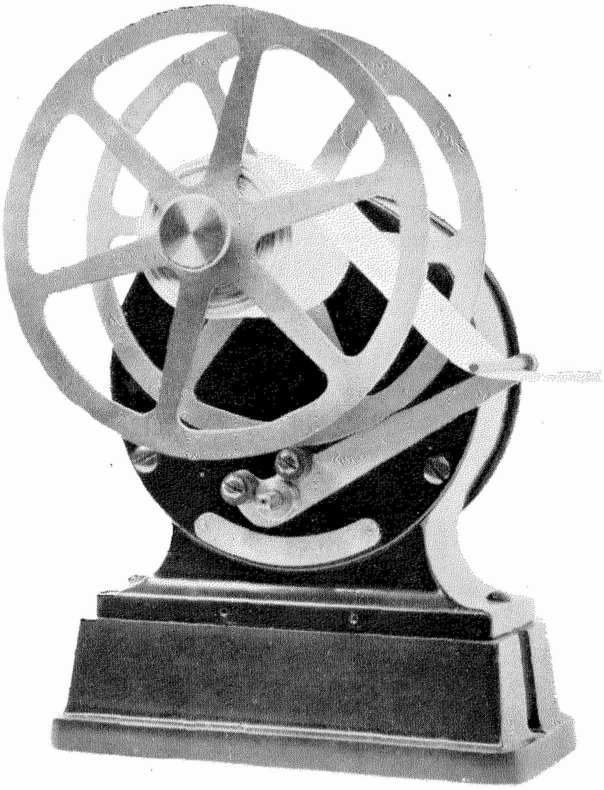


Figure 11—Paper Take-up Reel.

the current is interrupted. When the current is restored the armature of the register's electro-

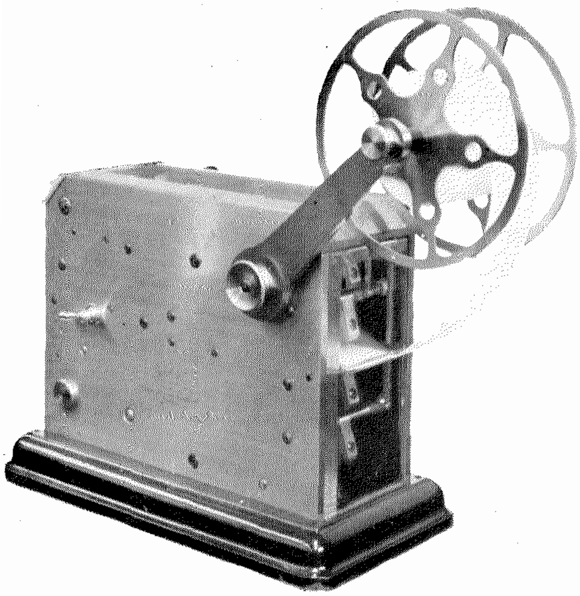


Figure 10—Multi-circuit Register Arranged to Receive Calls from Four Circuits Simultaneously.

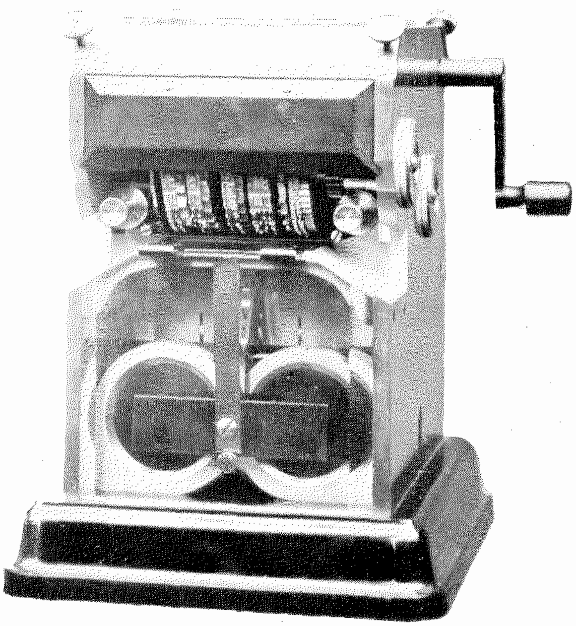


Figure 12—Time and Date Stamp.

magnet is reset ready to trip the mechanism on the next break of the current. Paper one inch wide is used in the recorder and at the completion of the code a local contact is closed, which operates a time stamp in order to stamp the exact time and date when the code is received. This register has two independent wheel trains driven from the same main spring, one to feed the paper forward, the other to drive the punch which is mounted eccentrically on one of the shafts of the wheel train. The "confetti" is collected in a small dust box located at the side of the register.

The Take-up Reel

The take-up reel, illustrated in Figure 11, is mounted about four feet away from the register, and is arranged to collect the tape as it is fed forward. A brake arm device ensures that all slack in the paper is always taken up, and in case the paper breaks or the reel comes to an end, the brake arm will drop down and still hold the reel from running away. The mechanism merely consists of a main spring and simple wheel train which is connected directly on to the reel itself, the brake being applied at the rim of the reel.

Figure 13—Register, Time Stamp and Take-up Reel as Mounted at Fire Station.

A different type of register has been designed to receive calls from more than one circuit simultaneously, and up to a maximum of six circuits. It is shown in Figure 10. The register is placed in a local circuit and fed from a 20-volt battery, the operating current being 220 milliamperes. The paper tape used with this register is two inches wide and is fed straight through the body of the recorder where it passes below a series of prickers each connected by a simple link mechanism to a separate electromagnet. Current in any one electromagnet depresses the associated pricker with the result that a triangular hole is perforated in the paper. As with the single circuit register, there is provided a local contact which is closed at a suitable time after the last punch is received on the register and which causes the time stamp to record the time and date on which the last code was received. The register also is fitted with a main spring controlled by an escapement which can be loaded mechanically to run at the correct speed. Here, the only function of the wheel train is to feed the paper forward.

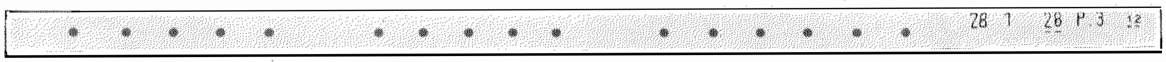


Figure 14—Paper Tape Showing Multi-punchings and Impress of Time Stamp.

Time Stamp

The time and date stamp illustrated in Figure 12 is mounted close up to the register so that the paper passing through the register to the take-up reel is passed directly beneath a series of type wheels on which are cast the years, months, days, and hours and minutes, both A.M. and P.M. Two electromagnets are used in the apparatus. One presses the paper on to an ink ribbon immediately below the type wheels, and is termed the printing electromagnet; the other is connected directly with the type wheels and to a master clock, and is arranged to receive one minute impulses in order to keep the type wheels at the correct time and date. Figure 13 illustrates the relative positions of the register, time stamp and take-up reel as arranged at the Fire Station, and Figure 14, the tape with multi-punchings and the impress of the time stamp.

GONGS

Gongs six inches in diameter usually are used, but they are manufactured in sizes up to fourteen inches. The six inch gong is illustrated in Figures 15 and 16. It has an electromagnet which, when released by the break of the current in the box circuit, trips the internal mechanism so as to throw the hammer smartly against the bell. It is automatically reset ready for the next break in the circuit. A main spring is used to drive a toothed ratchet which engages two stepping pawls arranged to make the hammer oscillate alternately into the centre of the mechanism and out to the edge of the gong as the ratchet wheel rotates. The electromagnet operates on the ordinary line current of 100 milliamperes.

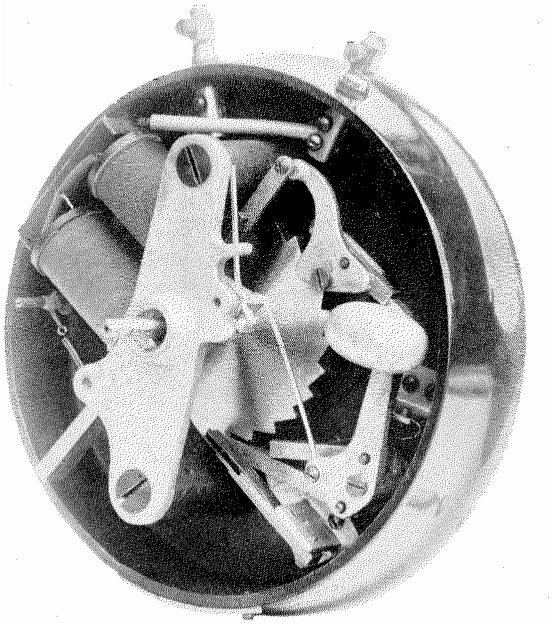


Figure 15—Gong with Bell Removed, showing mechanism.

Batteries and Control Board

Two batteries always are provided for every box circuit, the one being on charge while the other is discharging through the circuit. A make-before-break multiple throwover switch is used to effect the change over. The usual

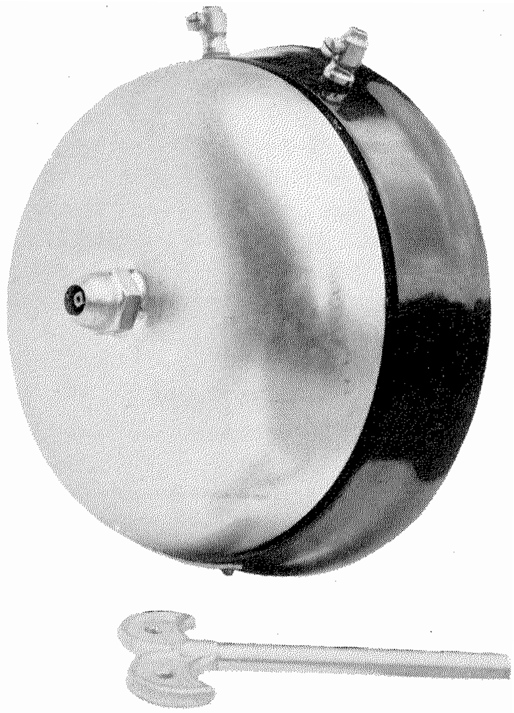


Figure 16—Gong for Audibly Warning the Brigade of the Number of a Fire-alarm Call.

charging and discharging instruments, fuses, line protectors and rheostats are provided, mounted on a slate panel. A voltmeter switch for testing to earth on both sides of the battery enables the Fire Station personnel to make routine tests for earth faults. Since no earth connections normally are used in the Gamewell System, the presence of the single earth has no effect on its operation; but it is usual to make these routine tests at least once a day in order to ascertain that the insulation resistance of the line is being maintained at a good level.

Rotary Automatic Telephone Service for Shanghai

By H. P. MILLER

Commercial Manager, China Electric Company, Ltd.

SHANGHAI, one of the most important trade centers in the Far East and the largest in China, has just completed the cutover of the first 5,000 units of a 7-A Rotary machine switching system. The equipment, which has a capacity of 10,000 lines, is being installed in the Central Exchange of the Shanghai Mutual Telephone Company which serves both the International Settlement and the French Concession.

The Shanghai Mutual Telephone Company was organized with 200 telephones in service in 1900, when the population of Shanghai comprised in the International Settlement and the French Concession was only about 500 foreigners and 345,000 Chinese. At present, there are five exchanges and nearly 25,000 telephones in use, and the population in the area in which the Telephone Company operates has grown to 40,000 foreigners and 1,000,000 Chinese.

It was nearly fifteen years ago that consideration was first given to the use of an automatic telephone system for Shanghai. In 1920 it was decided to install automatic equipment in East Exchange and a few years later a 500 line Ericsson automatic installation was made. Subsequently, it was increased to 1,000 lines. In view of a demand for more up-to-date service and other factors, it was decided also to install automatic equipment in Central Exchange, which furnishes service to the business district. Representatives and officials of the Telephone Company visited many telephone exchanges in Europe and America and made careful studies of the various types of automatic systems in use. As a result, it was concluded that the 7-A Rotary machine switching system was the most satisfactory. In 1924, a contract was entered into with Standard Telephones and Cables, Ltd., covering the installation of the 5,000 lines of 7-A Rotary equipment.

The climate of Shanghai is severe, with temperatures varying from 20° F. at times during the winter to a maximum of 110° F. during the summer. The relative humidity is particularly high, sometimes in the neighbourhood of 80 to 90 per cent for days at a time. These conditions naturally called for specially treated equipment throughout, including anti-rust treatment of all metal work, enameled conductors and impregnated insulation on all cables. Besides these

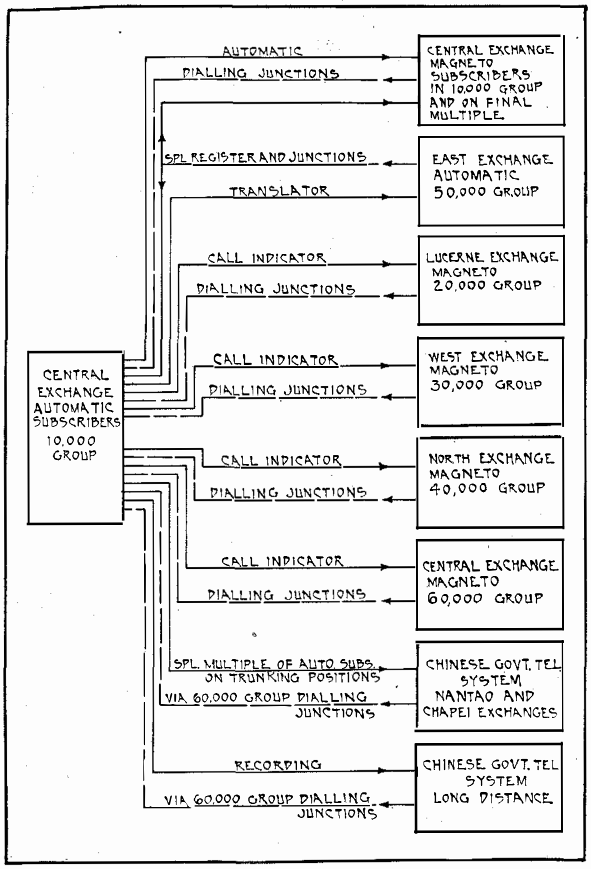


Figure 2—Method of Handling Calls between Central Automatic Exchange and the Other Exchanges in the Area.

safeguards, it was believed by the Telephone Company and its consulting engineers that more reliable operation and satisfactory service could be secured if the equipment was designed for 24-volt operation. Although this involved practically redesigning the 7-A Rotary equipment, it was taken care of satisfactorily by the engineering staff of Standard Telephones and Cables,

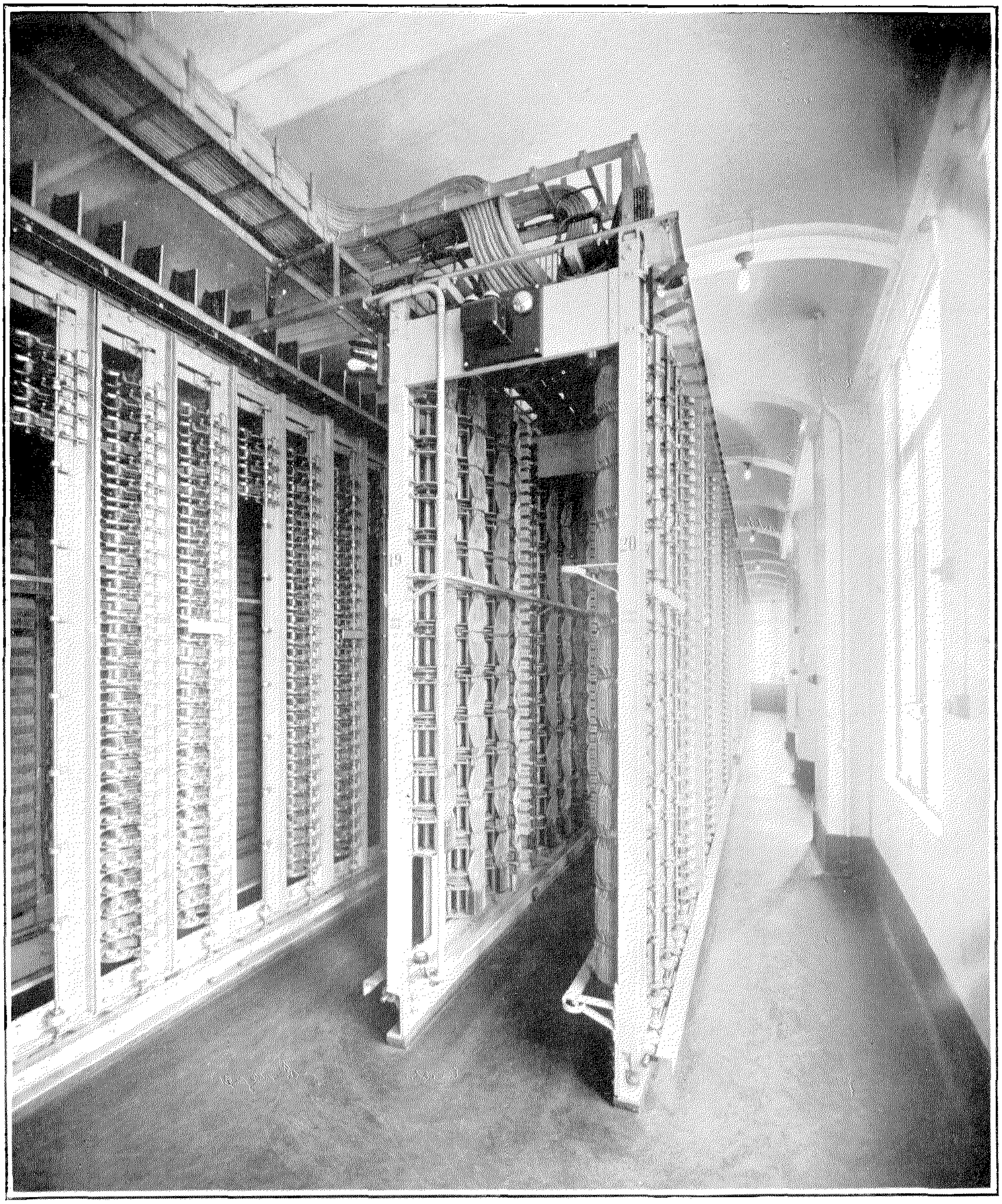


Figure 1—Line Finders and Selectors.

Ltd., London, and the Bell Telephone Manufacturing Company, Antwerp.

Previous to the cutting over of the 5,000 line unit of Rotary equipment, the Shanghai Mutual Telephone Company's network included the above mentioned 1,000 line automatic exchange and four magneto exchanges with switchboards equipped with lamp signals. Much of the outside plant was underground with but little aerial cable or open wire.

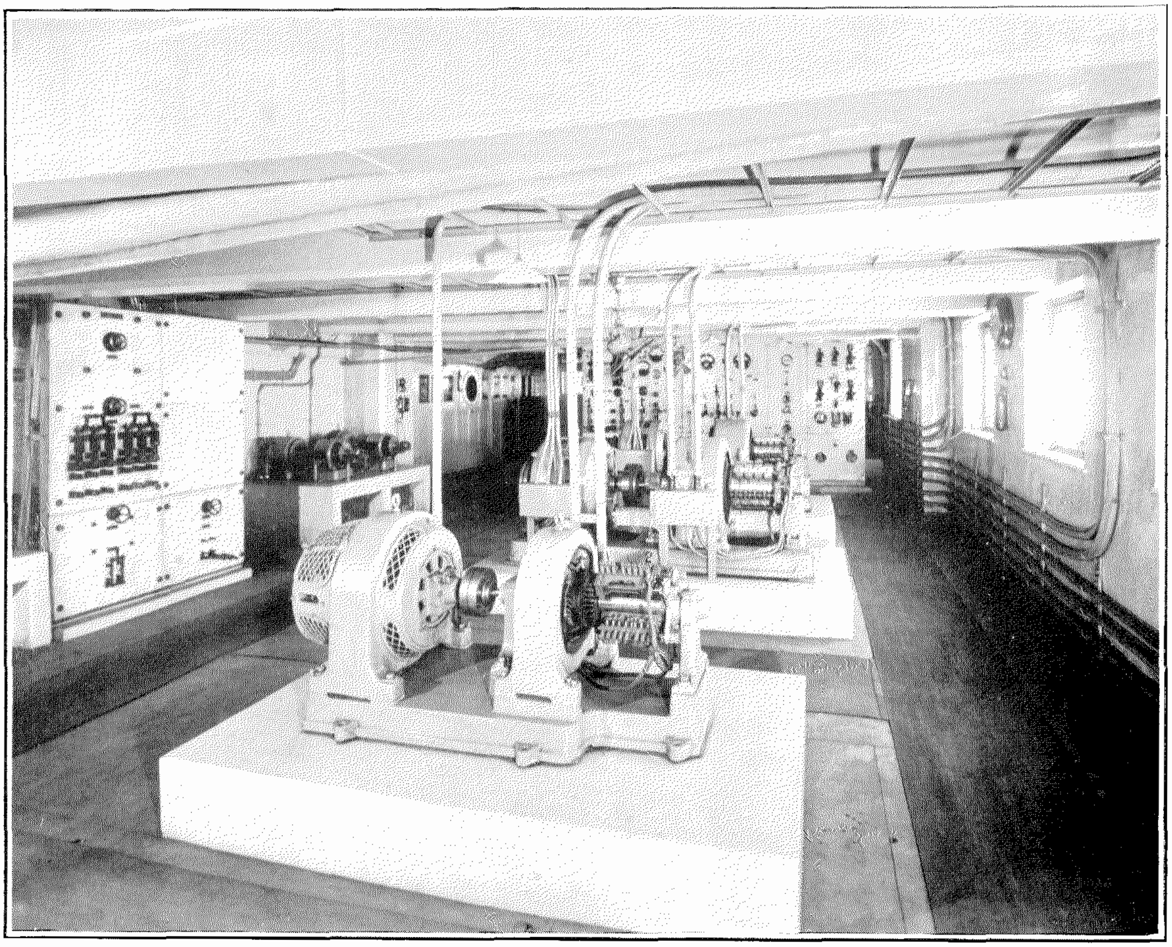


Figure 3—The Power Plant.

The initial Central Exchange automatic installation of 5,000 calling stations was arranged with final selectors reaching the entire group of ten thousand lines (Figure 1). Additional equipment is now being installed so that very shortly there will be 10,000 automatic telephones in Central District. To facilitate cutting over from the manual system to automatic, all the finals were multipled with 10,000 lines of the Central manual at the main frame. This procedure, of course, necessitated the use of considerable additional equipment but it was felt that the expense was fully justified, since automatic telephones could be substituted for manual at the subscribers premises at the convenience of the Telephone Company's staff and as rapidly as desired. It also enabled operators at the manual exchanges to become familiar with the dialing junctions and with methods, illustrated in Figure 2, of handling interexchange calls. It will be noted that dialing junctions are being used instead of semi-B positions at the manual exchanges. Semi-B positions would probably have been more efficient from a traffic standpoint but as these manual exchanges will probably be replaced by automatic equipment within a few years, the additional expense was not considered justified.

Incoming traffic from East automatic exchange to the Central automatic subscribers and also to the magneto subscribers in the 10,000 group is handled through special registers and junctions. Outgoing traffic from Central automatic to East Exchange routes through a translator, designed particularly for this service.

There is an increasing amount of traffic exchanged with the Chinese Government exchanges at Chapei and Nantao. Outgoing traffic from Central Exchange is handled through a special multiple of automatic subscribers (10,000 group) on a trunking position at which some subscribers are barred service. Incoming traffic to Central Exchange is routed via the 60,000 group dialing junctions. Outgoing toll traffic from Central Exchange over the long distance lines of the Chinese Government Telephone Administration is handled through a special toll recording position. Incoming toll traffic, as in the case of ordinary traffic from the Nantao and Chapei exchanges, is routed via the 60,000 group dialing junctions.

The entire 10,000 line automatic group is located on the third floor of the Central Exchange building, the main frame being located directly above on the fourth floor. The power room (Figure 3) is in the basement of the building. Here there is the necessary charging equipment, ringing machines and two 4,000 ampere hour storage batteries, the largest in the Orient. The frame motors are 200-volt 50-cycle single phase A.C. and are fed from the municipal electric service through a suitable switchboard. To provide for an emergency power supply should the ordinary source fail, there is installed in the power room a 200-volt 50-cycle single phase A.C. generator driven by a 24-volt D.C. motor. A relay on the switchboard starts up the motor generator set when the normal supply fails and the motor generator set is automatically cut out of service when the normal supply is again available.

Desk or wall sets with handsets or microtelephones are used exclusively. The dials are of special design, the lower or number plate rotating with the top or finger plate. Most of the dials are marked with Arabic numerals although some bear Chinese characters only (Figure 4). Single line subscribers or those with a single line and one

Figure 4—Calling Dials of Special Design. They are marked either with Arabic numerals or Chinese characters.

extension telephone only are connected to the new automatic exchange at the present time. In the case of subscribers with a single line and one extension telephone, arrangements are such that the main station, in addition to signalling and talking to the central office, can communicate with the extension station at the same time holding the central office call or connect the extension station with the central office.

When the additional 5,000 lines of automatic equipment which is now being installed is put in operation, subscribers with two or more exchange lines will be provided with common battery private branch exchange switchboards which will be equipped with dialing circuits. It is expected that before the end of the year the extension will be in operation with ten thousand telephones connected.

The new automatic equipment which has been placed in operation by the Telephone Company is functioning satisfactorily and the subscribers are highly pleased.

Transatlantic Telephony Between the Institution of Electrical Engineers, London, and the Institute of Electrical Engineers, New York

ON Thursday, February 16, 1928, a demonstration of transatlantic telephony was given between the Institution of Electrical Engineers, London, and the Institute of Electrical Engineers, New York, in joint session. By preliminary agreement, arrangements were made for receiving and for sending telephonic messages from the Council Rooms of the respective institutions and, in the case of London, provision was made by the British Post Office whereby an audience consisting chiefly of electrical engineers could listen in their Lecture Theatre to the proceedings, by the aid of a loud speaker. Immediately preceding the demonstration, a paper was read in New York by Mr. Waterson. This concluded at 3:25 P.M. (10:25 New York). In London the corresponding time from 3 P.M. to 3:20 P.M. was occupied by showing in the Lecture Theatre a film entitled—"Voices Across the Sea." At 3:20 P.M. those who had been invited to attend in the Council Room moved to their places and received a short explanation of the arrangements. This explanation concluded at 3:28 P.M.

After a few preliminary explanations to a corresponding meeting in New York, everything was ready, and by 3:30 the conversation began and continued somewhat as follows:

MR. CHARLESWORTH (New York): Good morning, Colonel Lee, is Mr. Page ready to talk?

COLONEL LEE (London): Good afternoon, Mr. Charlesworth, Mr. Page is ready to talk and I will hand the microphone to him.

MR. GHERARDI (New York): Good morning, Mr. Page.

MR. PAGE (London): Good afternoon, Mr. Gherardi.

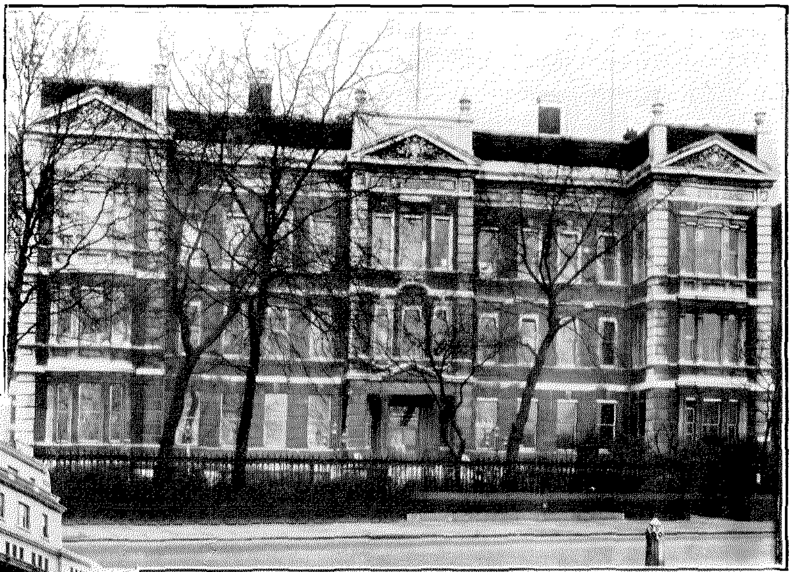
MR. GHERARDI (New York): Mr. Page, it would give us great pleasure if, as President of the Institution of Electrical Engineers—the senior society, founded in 1871—you would act as Chairman of this joint meeting.

MR. PAGE (London): I regard it as a great honour to be asked to take the chair on this historic occasion; it is also a gracious compliment to our Institution, and in accepting, which I do gladly, I desire to thank you, Mr. President, and the Members of the American Institute of Electrical Engineers most heartily. I welcome all present at the meeting now in session, and venture to predict that the proceedings will prove exceedingly interesting and likely to live not only in our memories, but to be quoted by succeeding generations of electrical engineers, as marking an important milestone in the advancement of electrical science. I am sure I interpret the desire of those assembled if I request Mr. Gherardi to address us, which I now do.

MR. GHERARDI (New York): Mr. President and Members of the Institution of Electrical Engineers: On behalf of the American Institute of Electrical Engineers, I extend to you greetings and our best wishes.

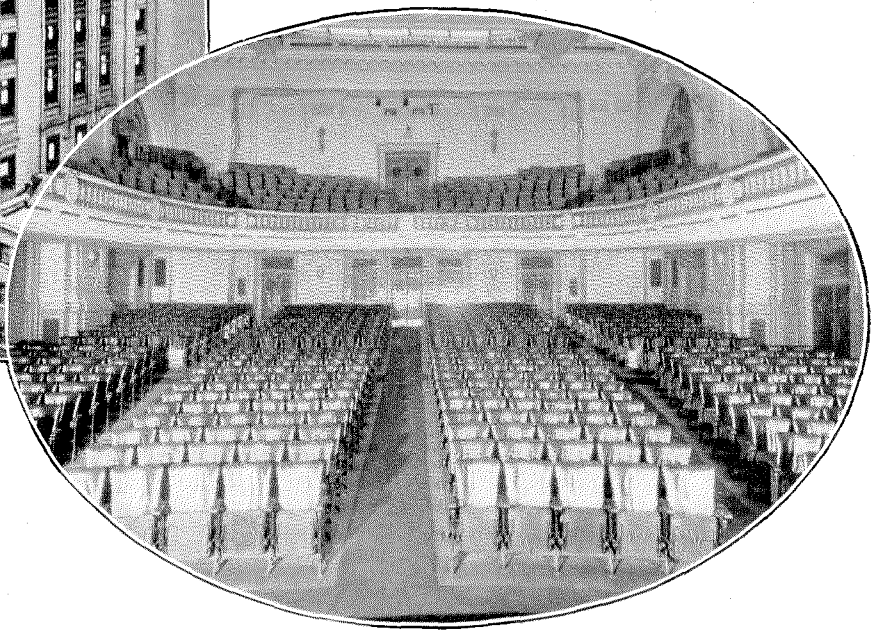
We are meeting here in New York at our Midwinter Convention. In the auditorium of the Engineering Society's Building in New York City, from which I am speaking, there are assembled about one thousand members of our organization from all parts of the United States, from Canada, and from other parts of the New World.

It is with the greatest satisfaction that, as a result of the accumulated work of the scientist, the inventor, and the electrical engineer, it is possible for us to hold this joint meeting—the first of its kind. It is with feelings of deep appreciation and respect that we think of the men who have exemplified the ideals of your organization—Faraday, Maxwell, Kelvin,—and of many others, past and present, who have contributed to electrical engineering and to the scientific foundations upon which it rests. These developments have been notable and have contributed in the greatest degree to the welfare of mankind. One of these developments is the art of electrical communication—the electric telegraph and the telephone. These have made communication independent of transportation, and no longer subject to all of its difficulties and delays. By the telephone, distance has not only been an-



The Institution of Electrical Engineers, London.

The Engineering Societies Building, in which the Headquarters of the American Institute of Electrical Engineers are located and in which New York City Meetings are held.



Auditorium of Engineering Societies Building, New York City.

nihilated, but communication by means of the spoken word has become possible. Starting in 1876 with instruments and lines, which with difficulty permitted communication over distances limited to a few miles, the telephone has been improved year by year until continents have been spanned, and at last, even the limitations of the Atlantic Ocean have been overcome, and today telephone conversation between the two great capitals of the English-speaking world is a reality. We are gratified that transatlantic communication has made this meeting possible; it has added one more to the many ties existing between our two institutions, and has added still another opportunity for friendly communication between us.

MR. PAGE (London): Mr. Gherardi and Gentlemen: Please regard me for the time being, not as Chairman, but rather as representing the 13,000 members of the Institution of Electrical Engineers. My first desire is to thank you, Sir, for your most kind message of good will to us all. In turn, we hail the President and members of the American Institute of Electrical Engineers with feelings of the utmost warmth, and of everything included in the term good comradeship.

Owing to the hour at which it has been necessary to hold this meeting falling within the period when the bulk of our members have to be on duty elsewhere, we have perforce had to content ourselves with a smaller gathering in London than that composing your convention. It is, however, of a thoroughly representative character consisting of specially invited distinguished guests, the Council of the Institution, many of whom have traveled long distances to be present, and a large percentage of the members of our Wireless Section.

The telephone must rank as one of the greatest inventions of the nineteenth century, and it has transformed the daily life of all civilized people. Our indebtedness to Graham Bell for the boon he has conferred upon us increases with the years, and his memory, along with that of Franklin and Henry, will be cherished as becomes such benefactors of mankind. It would indeed be a gigantic task to attempt to exhaust the list of those of your society who have contributed so largely to the progress of electrical science, and I must content myself by paying tribute to a great institution which has given proof time and again that engineering is truly international. It cannot be questioned that we are living in a period of extraordinary change due to scientific discovery, and in no field has the advance been more marked than in that of the communication engineer. The commercial radio services thus placed at our disposal assure closer and closer association between the English-speaking races, a new spice is added to life and the bonds of friendship materially strengthened. I rejoice that our two institutions can combine in the future even more effectively than in the past, and that this is the outcome of the splendid work done in one of the branches of our own profession.

I will now resume my chairmanship and call upon Dr. Jewett who is one of the Vice Presidents of the American Telephone and Telegraph Company, and a past President of the American Institute of Electrical Engineers.

DR. JEWETT (New York): Mr. Chairman, Mr. Gherardi, and Fellow Members of the Institution of Electrical Engineers and of the American Institute of Electrical Engineers: The opportunity which this occasion offers of addressing jointly two widely separated groups of engineers whom, in times past, I have addressed *vis-à-vis*, in London and New York, affords me the liveliest satisfaction. I am gratified to participate in an event which marks both a notable advance in electrical communication, and a pioneer demonstration of a wider use for electrical communication. I am frankly pleased that in common with numerous associates on both sides of the Atlantic, it has been my good fortune to play a part in the development work which has made this occasion possible.

Colonel Purves and Mr. Gherardi will remember, and the rest of you will be interested to know, that in London more than a year ago, when we were engaged in final considerations preliminary to the opening of commercial transatlantic telephony, we discussed details of just such a meeting as this. That our discussion should have been serious and not a pleasant mental diversion, at a time when the channels of communication were not in operation, is a striking evidence of the sound basis which underlies present-day electrical engineering. The fact that we saw and appraised the many obstacles to be overcome did not in the least diminish the assurance with which we talked of and planned for a distant event. While, therefore, the present occasion is highly gratifying to the engineers whose work has made it possible, it is in no sense a surprise. Success on this occasion is significant also in that it is the tangible evidence of a co-operation both intimate and full between men so situated as to make co-operation difficult. On behalf of my associates in America, I salute our associates in England.

(The Chairman (London), then called upon Colonel Purves, Vice President of the Institution of Electrical Engineers and Engineer-in-Chief of the British Post Office.)

COLONEL PURVES (London): Mr. President, Mr. Gherardi, Dr. Jewett and Gentlemen: It is an honour and a privilege to be associated with this notable event, which one can justly feel is breaking new ground in the advance of nations towards closer relationship. It is a great thing that two large assemblies separated by wide expanses of ocean, can join themselves together as we are doing now, and interchange their thoughts and ideas by the simple and natural medium of direct speech to a combined audience. It opens up the prospect of results which thrill the imagination, and which are bound to be beneficient, and to conduce, by the way of clearer mutual understanding, to the good of mankind.

On this first occasion it is inevitable that the many professional interests which our two institutions share—and which we should dearly like to talk over with each other—should be pushed a little into the background, and that we should find ourselves preoccupied mainly with the wonder of the thing itself. At our meeting here in London, we have just been shown a motion picture which illustrates in a very vivid and interesting way the initiation and progress of a transatlantic telephone conversation between San Francisco on the Pacific Ocean, and Plymouth in old England. We were not able—not yet able—to place it simultaneously before the eyes of you who are sitting there in New York, but some of you, at least, have seen it already. The greater part of it was made on your side, and I have to thank your President very heartily for letting us have the completed film. It helps one to recall, and to visualise, the remarkable series of new electrical developments—most of them things of only yesterday—which have combined to make this evening possible. The radio art has given us its essential basic principles, and the high-power amplifying tubes, which over here we call "valves"; long distance telephony has contributed a host of new devices which are equally essential, and specialised broadcasting has given us the loud speaking receiver. As we sit and talk to each other, our speech is launched into the air, by the radio transmitting stations at Rugby and at Rocky Point, with an electromagnetic wave energy of more than 80 horsepower, and I may add that the combined effect of the various refinements and special devices included in the transmitting and receiving systems is to make the speech carrying efficiency of each unit of this power many thousands of times greater than that of an equivalent amount of power radiated by an ordinary broadcasting station. Many further improvements are still being studied.

I should like to express the feelings of great personal pleasure with which I am listening this evening to the voices of my old and valued friends of the American Telephone and Telegraph Company, Mr. Gherardi, Dr. Jewett and General Carty, and to assure them and their colleagues, both on my own behalf and on behalf of the engineering staff of the British Post Office, that the increased opportunities of co-operation with them which the development of the transatlantic telephone system has afforded us, are appreciated in a very high degree. We have to thank them for much helpful counsel, in this, and in many other matters, and we look forward with great pleasure to a continuance of our close association with them on the long road forward, over which we still have to travel together.

THE CHAIRMAN (London): We are delighted to have with us in New York, General John J. Carty, Vice President of the American Telephone and Telegraph Company, and Past President of the American Institute of Electrical Engineers. General Carty is widely regarded as the doyen or, to be more correct, the Dean of the telephone engineering profession, and we shall be glad if he will say a few words and propose a resolution on the subject of our joint meeting.

GENERAL CARTY (New York): Whereas, On this sixteenth day of February, 1928, the members of the Institution of Electrical Engineers assembled in London, and the members of the American Institute of Electrical Engineers assembled in New York, have held, through the instrumentality of the transatlantic telephone, a joint meeting at which those in attendance in both cities were able to participate in the proceedings, and hear all that was said, although the two gatherings were separated by the Atlantic Ocean; and as this meeting, the first of its kind, has been rendered possible by engineering developments in the application of electricity to communication by telephone; therefore,

Be It Resolved, That this meeting wishes to express its feelings of deep satisfaction that, by the electrical transmission of the spoken word, these two national societies have been brought together in this new form of international assembly, which should prove to be a powerful agency in the increase of good-will and understanding among the nations; and

Be It Further Resolved, That a record of this epoch making event be inscribed in the minutes of each society.

THE CHAIRMAN (London): Sir Oliver Lodge, who needs no introduction, is sitting beside me, and I have asked him to second the motion.

SIR OLIVER LODGE (London): It is surely right and fitting that a record of the transmission of human speech across the Atlantic be placed upon the minutes of those societies whose members have been instrumental in making such an achievement possible, and I second the proposal that has just been made from America.

All those who in any degree have contributed to such a result—from Maxwell and Hertz downwards, including all past members of the old British Society of Telegraph Engineers—will rejoice at this further development of the power of long distance communication. Many causes have contributed to make it possible. That speech is transmissible at all, is due to the invention of the telephone. That speech can be transmitted by ether waves is due to the invention of the valve, and the harnessing of electrons for that purpose. That ether waves are constrained by the atmosphere to follow the curvature of the earth's surface is an unexpected bonus on the part of Providence, such as is sometimes vouchsafed in furtherance of human effort. The actual achievement of today at which we rejoice, and which posterity will utilise, must be accredited to the enthusiastic co-operation, and to the scientific and engineering skill of many workers in the background, whose names are not familiar to the public, as well as to those who are well known.

The union and permanent friendliness of all branches of the English-speaking race, now let us hope more firmly established than ever, is an asset of incalculable value to the whole of humanity. Let no words of hostility be ever spoken.

THE CHAIRMAN (London): Gentlemen, you have heard the Motion proposed by General Carty, and seconded by Sir Oliver Lodge. I now put it to the joint meeting. "Those in favour." "Contrary." "Carried unanimously."

THE CHAIRMAN (London): I suggest, Mr. Gherardi, that we now adjourn the meeting. I feel that it has been eminently successful and that we should regard it as the forerunner of many more to come.

THE CHAIRMAN (London): That is all the business, gentlemen. The meeting is adjourned. Good-bye.

The demonstration proved, in the most satisfactory manner, the complete feasibility of holding a joint session between two corporate bodies, even when they are separated by an ocean.

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