FROM TELEGRAPHY TO TELEVISION

THE STORY OF ELECTRICAL COMMUNICATIONS

By Lt.-Col.
CHETWODE CRAWLEY
M.I.E.E

FROM TELEGRAPHY TO TELEVISION

The Story of Electrical Communications

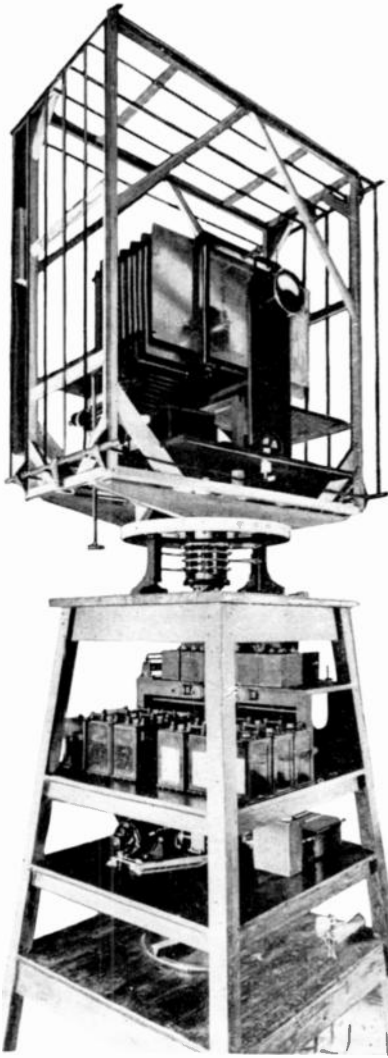
BY

LT.-COL. CHETWODE CRAWLEY, M.I.E.E.

WITH 44 ILLUSTRATIONS

FREDERICK WARNE & CO., LTD.
LONDON AND NEW YORK

Printed in Great Britain



Pl. I. *Frontispiece.*

A Rotating Beacon Station.

Showing the revolving loop aerial.

To

N., D. and M.

My "Good Companions"

"The world is so full of a number of things,
I'm sure we should all be as happy as kings."

Stevenson.

FOREWORD

INTEREST in wireless broadcasting has become so general of recent years that many people have gone a step further and have become interested in the whole field of electrical communications. For such there are numerous manuals that treat of special subjects, but few books, perhaps, provide in a consecutive form the links by which the stages of discovery and perfection can be intelligently followed.

This volume is intended to give a bird's-eye view of telegraphy and telephony in all their branches, showing their history, development, attainments and future possibilities, down to the latest scientific wonder, television, and it is my hope that in reading these pages "old men shall dream dreams, and young men see visions."

I take this opportunity of thanking Mr. A. L. Haydon for valuable advice and assistance in preparing this book for publication, and the Editors of *Television* and *Modern Wireless* for permission to make use of articles of mine which were published in those journals.

My thanks are also due to the following for permission to reproduce photographs: Imperial and International Communications Company, Ltd. (Plates V and VI); Marconi's Wireless Telegraph Company, Ltd. (Plates XI, XII, XIII, XIV, XVI, XVIII, XIX, XXII); Siemens Bros. & Co., Ltd. (Plate XV); and Baird Television, Ltd. (Plate XXIV).

C. G. C.

CONTENTS

LIST OF ILLUSTRATIONS

IN TEXT

CHAPTER I

LINE TELEGRAPHY

TELEVISION is the very latest development in electrical communication, but in studying the present we must not neglect the past. Mr. Hilaire Belloc rightly says: "Upon a just presentation of the past depends all our concrete judgment of the present." There are some who think otherwise and fondly imagine that they can appreciate the present without the trouble of studying the past. But they are wrong, and it is the hope of helping towards a concrete judgment of the present that must excuse this short—but, let us hope, just—presentation of the past. The subject is enormous, but even a bird's-eye view of an enormous subject must have some value, however small.

To begin with, the idea of communicating intelligence by some telegraphic method dates far back in history. The Greeks perfected a system of signalling with torches, and Chinese ingenuity long before Homer's time had devised some sort of telegraphic transmission by means of letters, numbers and codes. In Europe during the sixteenth and seventeenth centuries restless minds were at work endeavouring to improve upon old and clumsy efforts in this direction. Beacons had been used for signalling purposes. We may remember how, when the Armada appeared in sight,

"Twelve fair counties saw the blaze on Malvern's
lonely height;
Till, stream'd in crimson, on the wind, the Wrekin's
crest of light.
Till, broad and fierce, the star came forth on Ely's
stately fane,
And tower and hamlet rose in arms, o'er all the
boundless plain;
Till Belvoir's lordly terraces the sign to Lincoln sent,
And Lincoln sped the message on, o'er the wide vale
of Trent;
Till Skiddaw saw the fire that burned on Gaunt's
embattled pile,
And the red glare on Skiddaw roused the burghers
of Carlisle."

Among these early attempts at signalling, trumpets played their part. Up to a distance of nearly three miles the human voice was able to communicate through such instruments. Other experimenters in the realm of music turned their attention to bells, letters being indicated by a succession of graded notes. Following upon this came the study of the transmission of sound under water. This was a problem that interested Benjamin Franklin. The first big step in modern telegraphy, however, was taken by a Frenchman, Claude Chappe, who in 1791 instituted a synchronised system of signalling with two clocks, one at each station, numbers being transmitted by the sounding of a gong and these being interpreted into words.

Chappe abandoned his first system for that of the shutter, working with wooden frames on which opening and closing shutters communicated a code; but this in turn gave way to the semaphore. The success of the latter invention was marked. Chappe was hailed as a scientific genius and duly rewarded. Signalling by means of the arms of a semaphore and by the use of flags rapidly developed. Napoleon recognised its value and employed the system in military work. About this time the word " telegraph " —formed from the Greek *tele*, afar, and *grapho*, write—came into being, to persist as the description of all later improvements.

In this country both the shutter and the semaphore modes of signalling were adopted in the eighteenth century, with lines of communication between London, Plymouth, Portsmouth and other big ports for naval purposes. But the next century saw electricity make its claim and another great stride taken towards present-day developments.

The electric telegraph may reasonably be taken as the earliest form of electrical communication, just as television may reasonably be taken as the latest ; and as we can start with a Scotsman in the latest, so, too, can we start in the earliest. The later pioneer's name is well known to us all, but unfortunately we are not so sure of the earlier. However, even if he were not a Scotsman, he certainly wrote a paper in the *Scotsman's Magazine* in the year 1753, suggesting for the first time that messages might be sent by electric currents.

This famous paper, which was signed with the letters C. M., is generally believed to have been written by a Greenock surgeon called Charles Morrison, one of that gallant band of what the professionals call the amateurs.

It is a very remarkable fact, well worth the attention of young readers, that most of the pioneers of electrical communication were amateurs. The work of development fell mainly to professionals, but the amateurs undoubtedly carried off the palm of pioneering enterprise. The professional, if he admits that fact at all, will often say that the amateur became a pioneer overhead, but were laid in wooden grooves. So long as the wood kept dry all was well, but when it became wet the insulation broke down and the system became useless.

It is an historic fact that the railway authorities of that date doubted the practicability of the invention. Wheatstone and his partner had no little difficulty in convincing directors and engineers that their instrument was capable of meeting the demands made upon it. What helped to turn the scale in their favour was a demonstration of the public usefulness of the telegraph. This occurred on the Great Western Railway a year later.

A murder had been committed at Slough, the victim being a woman. On flying from the scene of his crime the murderer, a man named Tawell, took the train for Paddington, intending to hide in London. But the police were quick to make the discovery. Immediately a description of the wanted man was telegraphed from Slough to London (Tawell was referred to as a "kwaker," by the way, the instrument not having a "q" on its dial), and detectives who met the train at Paddington promptly arrested their man.

Such an incident as this could not but appeal to popular imagination. The fame of the "new telegraph" spread; its use became more general.

Eventually a double-needle instrument was designed with the object of reducing the number of lines to be maintained, and from this instrument the Single Needle, so well known on railways, was gradually developed. Wheatstone also invented the A.B.C. instrument in which currents from a hand magneto generator were caused to move a pointer over a dial bearing the letters of the alphabet. This apparatus was easily worked up to a speed of 15 telegrams an hour, and has only recently been superseded by the telephone in many village offices.

In America another inventor was pushing steadily forward on similar lines. Samuel Morse was a gifted American painter and sculptor, and did not even become a scientific "fan" until he was over forty years of age, when on a return voyage from England to America in 1832 he met an electrical expert in Professor Jackson. He witnessed some experiments carried out by Jackson on board the ship, and the good seed was sown. Morse at first knew nothing of electricity, but he sought the assistance of men who did, and by 1837 he had spent most of his money, but had constructed his first practical telegraph apparatus.

The ideas embodied in this apparatus are included in instruments still in use. About this time Morse went into partnership with Vail, a young American engineer who had helped him in his work. Morse brought his invention over to England but, like others we know of, received little encouragement here, and in 1840 was in sight of starvation. But he weathered the storm, and in 1843 erected the first telegraph line in America, between Washington and Baltimore, a distance of 40 miles. After eight years of poverty, fortune was achieved, and at the age of fifty-three his name was known all over the world.

It is now nearly a hundred years since Morse invented the dot-and-dash system of signalling, which, in spite of all the developments in telegraph working, is still the basis of the universal telegraph code.

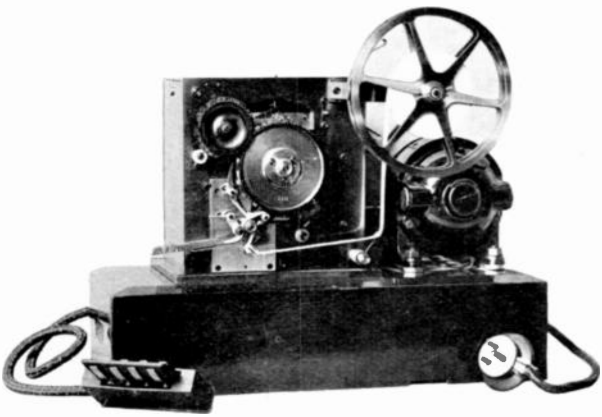
By 1850 it was clear that the telegraph had come to stay as a new means of communication, and we must now pass on from the pioneer stage to the modern stage of commercial practice.

For many years transmission was confined to sending messages in the Morse code by means of a hand-worked signalling key, and this arrangement is still, of course, used, but only on circuits where the volume of traffic is small. For other circuits, automatic sending of one sort or another has now been universally adopted.

At the receiving end, non-recording apparatus was at first supreme, but it is now confined to unimportant circuits with little traffic. The first non-recording instrument to be used extensively was the Single Needle instrument, which is now obsolete except on railways. It consists of a magnetised needle swung at its centre in a coil of wire. When the current from the line passed through the coil in one direction the needle swung to the left, which represented a dot; when the current was in the opposite direction the needle swung to the right, which represented a dash. In its later design this instrument became a simple and most efficient piece of apparatus with a working rate of up to 30 telegrams an hour.

The needle instrument was supplanted in the Post Office service by the sounder, which has had such a long life and such an extensive vogue that it must be familiar to many readers. It consists of an electro-magnet which can attract an armature fixed to a lever that is pivoted and moves between two stops. When the current from the line passes through the electro-magnet the lever is pulled down against the lower stop and remains down as long as the current is flowing. When the current ceases the armature is released, and a spring pulls the lever against the opposite stop. If a sending key is introduced into the circuit we have the means of sending or ceasing the current at will, and can send the dots and dashes of the Morse code, a dot being made by pressing down the key and immediately

The Baudot Keyboard.



Pl. II. *B 7.*

A Baudot Receiver.

releasing it, and a dash by holding the key down for the space of time required for making three dots. With skilled operators the sounder is good for 60 telegrams an hour.

It should be noticed, as the writer found to his cost in the war, that a wireless operator, used to reading wireless Morse signals in a telephone, is perfectly useless on a sounder until he has had considerable practice, as the sounder signals are quite different from the buzzing telephone signals. In fact, a wireless operator can read a flashing lamp much better than he can a sounder, though he may never before have used his eyes for reading signals.

The sounder is the best, and the last, of the non-recording instruments so far as line telegraphy is concerned, and we must now pass on to recording instruments which have been descending upon us like a shower of meteors for the last quarter of a century.

CHAPTER II

MACHINE WORKING

THE first recording instrument was made on the lines of the sounder, a steel style being brought into contact with a paper tape drawn along by clockwork, but this was soon supplanted by an ink-writer which was invented as long ago as 1854 by John, an Austrian engineer. John used the same principle, but substituted a wheel for the style. The wheel was revolved by clockwork, which also propelled the tape, and its lower half dipped into an ink reservoir. As the armature was attracted the wheel pressed against the tape and made a mark, a long one for a dash and a short one for a dot. All the Morse printers which have since been developed are mechanical improvements of John's instrument.

Many excellent recorders were designed and tried in those early days, but practice lagged behind invention, primarily because the volume of traffic did not justify their development for commercial service. However, in due course, telegraphic business began to increase so rapidly that it became essential to increase the traffic capacity of lines on the more important routes, and serious attention was turned to automatic working.

The first automatic apparatus to be used extensively in this country was Wheatstone's equipment, and in its later form it is still used on some circuits. The apparatus consists of a perforator for punching holes in a paper tape which is then fed into the sender, and at the receiving end is a printer, on the general lines of John's instrument, which prints the Morse code signals on a paper tape. The message is first punched up on the tape in the Morse code; three punched holes in one vertical line correspond to a dot; one hole in the middle corresponds to a space, and four holes (one above, two in the middle, and one below) correspond to a dash. The holes in the centre are smaller than the others, and are only for use in connection with the mechanism for moving on the tape. When the punched tape is passed through the transmitter by clockwork two vertical rods press against it, and every time the holes come along the rods pass through and make electrical contacts, by which means the message is transmitted along the line in the Morse code. The message is received in the form of dots and dashes on the tape of the printer, and is written up by hand or typed on the telegraph forms.

In the later forms the punching of the tape at the transmitting end is done by an operator on a typewriting keyboard. That is to say, a sending operator transmits by working an ordinary typewriting keyboard, and a receiving operator types up the message, which comes to him on a paper tape in the dots and dashes of the Morse code. This apparatus has been vastly improved in detail by the engineers of the Post Office, and it is still one of the finest equipments available for the rapid disposal of traffic, at speeds up to 400 words a minute.

Much time is, of course, occupied in typing up, or writing out, the message from the tape, and to obviate this a most ingenious receiver, invented by Mr. Creed, of England, is now extensively used. With this apparatus messages can be received up to a speed of 125 words a minute in printed characters on a gummed tape, which is stuck straight on to the telegraph form.

So far we have been considering what is called simplex working, that is, the transmission of only one message at a time over the circuit, but the traffic over one line is often so heavy that some form of multiplex working is required. In this country the standard practice for the most heavily loaded circuits is, now, to send four messages and receive four messages simultaneously over the same line on what is called the Baudot system.

The total number of words a minute that can be dealt with by this arrangement is 240 by manual, or 400 by automatic transmission. The original apparatus was invented as long ago as 1874 by Baudot, a Frenchman. His apparatus was not welcomed at first even in his own country, and was not introduced over here until 1897. Indeed, the whole story is one long tale of tragedy, and Baudot himself, one of the greatest inventors in the annals of modern telegraphy, worn out by worry and disappointment, died in a lunatic asylum.

The Baudot is a five-unit system, the messages being sent, not in the Morse code, but by a combination of five positive or negative impulses. Hand transmission gives a speed of 30 words a minute, and up to 50 words a minute can be obtained by automatic transmission. In the latter case typewriter keyboards are used for the perforation of tape, which is automatically fed into the machine transmitter. At the receiving end, in both cases, the messages come out as printed letters on the paper tape.

Another important machine system, which is still used on many continental circuits, was invented in

1854 by Professor David Hughes, of England, so famous as a pioneer in wireless and as the inventor of the microphone. The Hughes system is not now used in this country except on some cross-channel circuits. The transmitting keyboard is like that of a piano with 28 black and white keys, and the letters are produced by single signalling impulses separated by a variable number of units of time. It can work up to 50 words a minute simplex, or 100 duplex, but is not adaptable for multiplex working, and cannot therefore take the place of the Baudot on heavily-loaded circuits. The receiving apparatus works in synchronism with the sending apparatus, and the messages are printed on a paper tape. The system has certainly some unique advantages, and it is unfortunate that it cannot be adapted to modern multiplex equipment.

In recent years the teletype, or, as it is usually called in this country, the teleprinter, has been taking the place of the Wheatstone, Baudot and Hughes apparatus both here and in other countries. This apparatus consists of a typewriting keyboard transmitter and a printing receiver. The typewriting keyboard sets up the combinations of five units, and these impulses are transmitted direct to the line without the interposition of perforated tape. At the receiving end the messages are printed on tape, as in the case of the Creed and Baudot apparatus. It works up to 60 words a minute simplex or 120 duplex, and there is no doubt that this ingenious system will have a great future in developing the telegraph service of this country, where it is already being worked on many important circuits.

We come now to the telegraph service which, in this country, as in other European countries, is State-owned, having passed under the control of the Post

Office in 1870. By 1885 it was showing signs of paying its way, but in that year the House of Commons, against the advice of the Government, introduced the sixpenny telegram, since when the service has never shown any signs of being a financial success. In 1920 the shilling telegram was introduced, but this doubling of the tariff has hardly counterbalanced the increased costs due to the war, and to the decline of traffic, which is due mainly to competition from the telephone.

There is, in fact, no chance of the telegraph service paying its way so long as wages and prices remain anywhere near their present levels. The annual loss before the war was about £1,250,000, but it is now rather less. The traffic has dropped from about 94 million messages to about 64 million messages a year, but the ideal of service at which the Post Office aims remains unaltered, viz., a really good service of uniform quality to all places, large and small, and this, let it be noted, is an ideal of service which would not appeal to the shareholders of a commercial company.

In the following chapter we shall deal more particularly with this branch of the G.P.O.

CHAPTER III

AT THE CENTRAL TELEGRAPH OFFICE

ONLY by paying a visit to the Central Telegraph Office in London can one hope to obtain any idea of the immense volume of work which is carried on over the inland and Continental wires. Figures—huge figures—may be thrown at the inquirer. He will be informed that an average of 30,000 telegrams per day is despatched from one part of London for delivery in another; that the number of telegrams handled by the office daily is anything between 120,000 and 165,000, and that in a year it totals close on 45 millions; that between 18,000 and 30,000 telegrams pass daily over the cables in the Continental traffic. These statistics are impressive, but what they actually indicate cannot be grasped until one has seen the various departments at work in this hive of industry.

It is fifty-seven years since the Central Telegraph Office—the largest in the world—was opened in St. Martin's-le-Grand, London. Before then, from 1860 to 1874, its building was appropriately in Telegraph Street, E.C., whence it had removed from Lothbury. Its expansion has been rapid; the staff, formerly less than 1,500, is now about 4,000. The Central Telegraph Office is the hub of telegraphic communication in Great Britain, being linked up with every important town and with every telegraph office in the metropolis.

In its organisation the C.T.O. comprises three main sections: the Metropolitan, Provincial and Foreign. In addition there are special branch telegraph offices at the Stock Exchange, Threadneedle Street and Commercial Sale Rooms. From the Threadneedle Street Office direct wires run to several Continental offices and to the larger provincial towns. The building itself is laid out as follows: on the ground floor, the public counter, the delivery room, the accounts section, the telegraph school, the central hall with tubes to and from the larger London telegraph offices; on the first floor, the phonogram room, medical and administrative offices; on the second floor, circuits for foreign traffic, central radio office, private telegraph and tube circuits; on the third floor, provincial circuits and other tubes to London offices; on the fourth floor, metropolitan and home counties' circuits, and the teleprinter exchange; on the fifth floor, workshops and staff rooms. In the basement are stored the batteries and dynamos that supply the electric current required, together with the compressors that work the pneumatic tubes, to which reference will be made later.

The School of Telegraphy deserves a passing reference. Here candidates, both male and female, for the Telegraph Service in London, who have passed the necessary Civil Service Examination, are put through courses of instruction. The pupils are instructed in the use of instruments and other technical details until they are certified as being competent to take charge of a circuit. When so certified they receive appointments on the staff as vacancies occur.

The telegraph system has made great strides since the adoption of the single-needle machine and the time when a carbon copy of every telegram was made and preserved as a check upon complaints; when, too, a less rapid messenger service was in operation. The

At the Central Telegraph Office, London.

A gallery dealing with telegrams to and from London offices.

Pl. III. *B* 14.

The Central Hall, Central Telegraph Office, London.

Showing (right) pneumatic tubes serving the principal London offices.

sending and delivering of telegrams has been speeded up to a remarkable extent. Take the instruments alone, for example. In 1870 the capability of a wire was a single channel of Morse communication. The duplex system followed, enabling messages to be forwarded on a wire at the same time in both directions; from this developed the quadruplex and multiplex working, it being possible in the last-named for a single circuit to yield six channels of communication in each direction, *i.e.*, twelve in all.

The evolution of the instruments in use, the machine telegraphs, has proceeded along the same lines. In the earliest days, as already mentioned, the Cooke and Wheatstone needle telegraph system required four line wires. That was as far back as 1835. Next came the double-needle system with two line wires, to be superseded by the single-needle requiring only one line wire. After these we have the developments brought about by the improved Wheatstone's A.B.C., Bright's Bell, Morse's Printer and Sounder, the Wheatstone Automatic, the Hughes, Baudot, Creed, Murray and Teleprinter systems, the working of which has been dealt with in Chapter II.

To explain briefly what these successive stages imply, it should be pointed out that telegraphy has undergone two main developments: that in which Morse symbols are employed, to be translated mentally by the operator into letters and figures, and that by which special electrical signals are translated into printed characters at the receiving end. This latter development embraces the Hughes and Baudot machines. Similarly the Creed instrument translates the Morse signals into Roman type.

Up in the Instrument Galleries, which occupy the whole length and breadth of the great building, one sees these machines at work—long lines of them with men and women operators busily engaged in dealing with the succession of telegrams passing under their hands. As the instrument clicks out its response to the quickly-tapping fingers of the distant sender a slip of paper comes from the receiver with the message printed in block letter capitals; as the telegram is checked and finished it drops into a moving carrier at the back of the table on its way to be collected and dispatched.

While on inland circuits the Morse Sounder is still sometimes employed (it can be worked by hand at a rate of about 25 words a minute), it is the Wheatstone Automatic and the Teleprinter that serve for the handling of telegrams in great volume.

The labour-saving and time-saving advantages brought about by these developments in machinery are striking. Whereas fifty years ago—less than that, perhaps—fourteen operators and seven wires would have been necessary to perform the same work, now some eight operators working automatic instruments on a single circuit can transmit anything up to 400 messages in an hour. And now this "multiplex," as it is called, is beginning to give way to the teleprinter.

Apart from the main telegraph service the chief points of interest in the C.T.O. departments are the phonogram room and the private telegraph wires in connection with banks and large business houses. The latter is an important modern development, for this time-saving method spells money to the financier and the commercial magnate. The teleprinter is being tried on some of these circuits. In this connection, too, it may be noted that the Stock Exchange is privileged above all other private wires to use distinctive delivery forms.

The phonogram room is one of the busiest in the whole building. Here hundreds of women and girls, in long lines at the tables, are handling messages that come in by telephone. The convenient method of dictating a telegram to the nearest telegraph office through the telephone is becoming more and more popular, especially as the latter instrument is available after a telegraph receiving office is closed. About 10,000 telephone-telegrams are received and delivered each day in London. For long distances, too, business men are employing this method, often finding it quite as satisfactory (while it is cheaper) as making a trunk call.

Another feature in speeding up the handling of large volumes of traffic is the installation of 52 pneumatic tubes. Through these, telegrams are dispatched swiftly in cylinder carriers to and from the Central Office and the chief post offices in the City and West End of London. There are also special tubes which are connected with the House of Commons, foreign cable companies' offices and the Press Association, among other important organisations. In some post offices there will be two tubes, one for the despatch of telegrams and the other for reception. The working of the pneumatic tubes is done by compressed air for outgoing carriers and by a vacuum for incoming ones. These are the main tubes; for the purpose of dealing with telegrams from point to point in the different galleries local tubes are provided (five miles of them in all), and these are in constant working throughout the day. In addition to this ready service there are cord and band carriers, so that no telegram, outgoing or incoming, can have any reasonable excuse for lingering on the way.

What else does the Central Telegraph Office do in the matter of serving the public ? For one thing it acts as timekeeper throughout the kingdom. By means of two chronofers fixed in the Provincial Gallery, Greenwich time is distributed daily to all the cities and principal towns. Apart from a special time signal given to some selected places at 1.0 p.m., this timing is carried out at 10.0 a.m. At 9.0 a.m., too, every telegraph office in the country that is not connected with the chronofer receives a time signal from the Central Office, thus ensuring that the correct time shall be noted on all telegrams, etc. In addition, a world-wide time signal is given by wireless from Greenwich through the C.T.O. and the high-power Station at Rugby.

Then there is the Cable Room, whence the wires are busy dealing with telegrams to the Continent, to Belgium, Holland, and Germany, to Spain, Italy, Switzerland, Austria and countries beyond. As may be supposed, the greatest volume of traffic is that to Paris, in which some 20 channels are usually being worked. The Baudot telegraph system is mainly employed, four-channel and six-channel Baudot installations proving very successful. In this foreign work a special staff with linguistic qualifications is engaged. A knowledge of French and German is essential to the candidate for appointment in the Cable Room ; many operators qualify for positions by acquiring a working knowledge of several other languages.

The Post Office controls the working of a large number of telegraph and telephone submarine cables, 200 or so in all, which connect England with Ireland, the Channel Islands and various islands round the coasts, together with others linking up the Continent. Until 1929 the Department worked the two imperial cables to Canada, but these were sold to Imperial and

Pl. IV.

C 19.

The new Telegraph Instrument Room at Leeds.

International Communications, Ltd., for £450,000 when that company was formed as a merger of cable and wireless interests in this country. The beam wireless telegraph services to the Dominions and India which were also previously worked from the Central Telegraph Office were in like manner handed over to the merger company for £60,000 on lease at £250,000 a year. The speed at which cable communication can be effected has now reached an extraordinarily high standard. From the London Stock Exchange, for instance, a cable can be sent to the New York Exchange, and an answer received in a couple of minutes.

How speedily cable communications are dealt with at the Stock Exchange on this side is demonstrated constantly at Shorter's Court in the City. Here, in the "street market," a chain of messengers passes the cablegram from hand to hand with the utmost celerity into the House, where it is rushed to the addressee. Large sums of money frequently depend upon these messages, and this system of delivery, though apparently primitive, is sure and speedy.

Important work is further performed by the Central Telegraph Office in regard to the Press, though the Press Association now has its own system of distribution. Every day a vast amount of news matter passes over the wires in this country. Fleet Street can testify to this. When Parliament is sitting many hundreds of thousands of words are sent off, and on a big night in the House—such a night as when a momentous Bill is introduced or a statement of world-wide import is made by a Minister—the total may reach a million.

Finally, mention must be made of the particular department—a fairly recent innovation—which undertakes the work of picture transmission by telegraphy. As noted in Chapter XXII, the public has yet to grasp the facilities in this direction that are afforded by the C.T.O. The Press and the Police are alive to the importance of this section. By means of the delicate machinery installed (particulars of this are given on page 167), the most faithful reproductions of photographs, sketches, technical diagrams and other designs are transmitted to or from the C.T.O., much of such work being performed in connection with the Continent.

The nature of the picture transmission is varied. Photographs of criminals or suspected persons may be passing from one police authority to another. Scientific formulæ, maps, shorthand, intricate drawings and matter printed in foreign characters, which can only be sent otherwise by post, are included. In addition the service is used for the purpose of forwarding private transcripts and personal greetings (often accompanied by a photograph of the sender), while advertisements of a pictorial character are dealt with.

A high pitch of excellence in the result of this transmission has been reached, and the service, which touches such places as Paris, Berlin, Vienna, Frankfurt, Munich and Scandinavia, will be extended as requirements permit.

From this summary, all too short to do justice to a Government department of such magnitude, it will be comprehended that the Central Telegraph Office, with its ever alert day and night staff, performs a work of great national utility. It is alive to the needs of the community that it serves, and with the advance of science it takes advantage of every possible mechanical development to further the efficiency of its equipment.

CHAPTER IV

SUBMARINE TELEGRAPHY

WE have seen how credit for early developments in line telegraphy fell chiefly to Great Britain, America and Germany, but early developments in submarine telegraphy may be credited to Great Britain in the first place with the United States of America as runner-up.

The first messages sent by submarine cable were probably those transmitted across the river Hooghly, in India, by Brooke, an Englishman, in 1838, an experiment of note. Sir William O'Shaughnessy Brooke—he was known as Dr. O'Shaughnessy at that time—was connected with the East India Company. For insulation he enclosed his wire (previously pitched) in a split rattan which was wrapped round with tarred yarn, in this method forestalling the devices of Wheatstone when he put forward the project of establishing underwater telegraphic communication between Dover and Calais. About the same time our old friend Morse, of America, sent messages across the harbour of New York. Morse, as we have seen, was then in the throes of poverty, and it was at this time that he wrote, as has often been quoted, " My stockings all want to see my mother, and my hat is hoary with age."

Ezra Cornell, of America, the founder of Cornell University, carried out some successful experiments a few years later, and in 1846 Charles West, of England, had some success with a submarine cable at Portsmouth. West, like Morse, failed for want of money, and in this incident will be seen the reason why, unlike what we found in line telegraphy and what we shall find again in telephony, amateurs have had to yield the palm to professionals in the technical pioneer work of submarine telegraphy.

It is obvious that experiments in submarine working must be very costly compared with line working, and the amateur experimenter is not, as a rule, a man of great wealth. Neither, for that matter, is the professional, but, other things being equal, wealthy men are more likely to back the professional than the amateur. That is what happened with the first Atlantic cable. To his everlasting credit Cyrus Field, an American millionaire, had the vision to finance the scheme.

But we are going too fast. The short submarine cable was a practical proposition before Field stepped in, largely due to the untiring industry and enthusiasm of the brothers Brett, of England, who, entirely at their own expense, laid the first cable across the English Channel from Dover to Calais in 1850. Composed of gutta percha insulated wire, it had 30 lb. weights of lead attached to it at intervals of a hundred yards to effect its submersion. To the amusement of an incredulous public it transmitted but a few words—a brief message to Prince Louis Napoleon Bonaparte; then a French trawler hooked the line by accident and put it out of action. The world laughed at the story, and at the idea of a submarine cable, but it had served its purpose; it was replaced, and others followed.

Cyrus Field came to England and with others over here backed the Bretts financially, and had the good fortune to enlist the help of Charles Bright, an English electrical engineer. Bright—he became Sir Charles later—was a born pioneer. He had all the attributes—courage, enthusiasm, ability, and, perhaps not least, poverty and youth. Not poverty of the "hoary-hat" variety, for poverty, like all else, is comparative. Before he was twenty he was well known in what was then the small telegraphic world; before he was forty he was known as "the father of the Atlantic cable."

Field's driving power and Bright's technical ability were fortunately supplemented by the genius of Thomson, but unfortunately clogged by the stubbornness of Whitehouse, who had been appointed engineer-in-chief of the scheme. William Thomson, afterwards Lord Kelvin, was an Irishman of Scottish descent. His father's people had come to Ireland from Scotland some two hundred years before, and his mother was Scottish, but he was born in Belfast and can be justly claimed by Ireland. And William Thomson is well worth claiming. He was one of the greatest scientists and one of the greatest inventors, not only of our country, but of the world. At first Thomson was merely on the board of directors, and it was not till August, 1858, that he was appointed engineer-in-chief in place of Whitehouse, whose attitude, to put it mildly, had become insufferable.

Thomson's advice on all matters, and his practical assistance in carrying out tests on the cable, were invaluable. He applied the principles of his mirror galvanometer not only to testing the cable, but to the reception of signals. With Whitehouse's receiver it took 16 hours to pass the first message of 99 words from our Queen to the President of the United States. At this end, where Thomson's receiver was used, it took 67 minutes for the message to be repeated back.

It must be understood that signals through a submarine cable are not only attenuated, but they are very distorted. The signal, in fact, takes an appreciable time to die away, and if the Morse code were used, the dots and dashes would run into one another unless the speed of signalling was extremely low, which is quite out of the question for remunerative working.

It was Thomson who first devised a suitable method for sending and receiving signals. He invented the impulse method of signalling, in which a dot is represented by an impulse of positive current of the same length, and a space between letters by a corresponding zero interval, the message being recorded on the receiving tape in the form of a wavy line.

The receiver which Thomson invented, and which is still used on some cables, is the Syphon Recorder. It consists of a small glass tube shaped like a syphon, with one end immersed in an ink-well, the other end being free to move to and fro across the surface of a paper tape. The syphon is connected to an electromagnet in the line circuit in such a way that currents in the line produce movements, to and fro, of the syphon across the tape. When the syphon is at rest a straight line is drawn on the tape, but when in movement a wavy line, whose characteristics depend on the signals being received.

But we anticipate again. Field and his English friends, John Watkins, Brett and Charles Bright, lit the cable torch so well on both sides of the Atlantic that even the Governments succumbed, and on August 6th, 1857, an expedition for laying the first cable set off from Valentia on the south-west coast of Ireland. Each Government had supplied a warship; the American ship, the frigate *Niagara*, was to lay the first half of the cable from Valentia, and the British ship, H.M.S. *Agamemnon*, was to continue it from mid-Atlantic to Newfoundland. Other vessels acted as escorts, the little fleet earning the name of "the Wire Squadron."

Unfortunately, 400 miles out, the cable snapped, and the ships came into Plymouth. More money had to be raised, and again the expedition started off in June, 1858. Terrific weather was encountered, and again there was failure. But once more the money was forthcoming, the attempt was made, and, as in all good fairy tales, the third attempt was crowned with success.

What had been the experience of the two cable-laying ships is really worth more than a passing reference. Terrific weather, it has been said, was encountered in the Atlantic. To be exact, one of the fiercest storms on record fell upon the vessels. The *Agamemnon* suffered most among the little fleet; only by superb seamanship was she saved from disaster. A newspaper report stated that the lurch of the ship was calculated at "forty-five degrees each way" for five times in rapid succession. In two black days and nights of terror there were many casualties, but the crew worked heroically, until the gale blew itself out.

Although the American *Niagara* had been badly knocked about she had weathered the storm successfully. Just six days after running into this gale the end of the *Niagara's* cable was sent aboard the *Agamemnon* to be spliced. A bent sixpence was put into it "for luck," and then the great coil of wire was dropped into the ocean depths. The expedition seemed to be fated, however, to meet with trouble. In about an hour's time the cable broke as it was being paid out from the *Niagara's* deck. So a fresh splice had to be made, but the operation had to be repeated a day later. This time the fracture took place below the water, the occurrence giving rise to much conjecture on the part of scientists as to the nature of the ocean bed. After this matters went well and 146 miles of cable had been paid out when suddenly the *Agamemnon's* machinery stood still: the cable had parted yet once more, and the broken end swung loosely over the stern.

On July 4th the *Agamemnon* returned to the appointed rendezvous in mid-ocean to meet the *Niagara*, only to find that the latter ship had gone back to Queenstown. On shore there were those who counselled an abandonment of the expedition, but the projectors and their supporters gained the day. It was decided to make another attempt. The cable ships left Queenstown on July 17th, with gloomy forebodings in the minds of most who watched their departure, but this time, apart from more heavy weather and a scare from a huge whale that might have fouled the cable, the *Agamemnon* reached the Irish coast and came into the bay at Valentia. The *Niagara*, for her part, had made good her passage to America.

On August 5th Charles Bright had the satisfaction of sending the following message to his *confrères* in London: "The *Agamemnon* has arrived at Valentia, and we are about to land the end of the cable. The *Niagara* is in Trinity Bay, Newfoundland. There are good signals between the ships." It was now realised on both sides of the Atlantic that the seemingly impossible feat had been accomplished. The submarine link between the Old and the New Worlds was no longer a dream.

For his work in this great enterprise Charles Bright was knighted.

It does not sound much in the telling, but that is only because the difficulties were so great that even a summary of them would require the space of a whole chapter. All we need say here is that the laying of the first Atlantic cable will rank for ever as one of the epics of scientific achievement.

This cable only lasted two months, but over 700 messages had been sent, and the possibility of long-distance submarine telegraphy was proved beyond a doubt; and it was doubt that had been the greatest obstacle of all, as, indeed, was again the case when Marconi was trying to span the Atlantic by wireless telegraphy, 44 years later. It was largely a triumph of youth and enthusiasm. Bright, like Marconi, was only 26 years old when he conquered the Atlantic.

The next attempt was made in 1865, and the largest ship afloat, the *Great Eastern*, was used for the purpose. The cable was much stouter than before, and weighed 4,000 tons, but it broke in the laying, and it was not until July 27th, 1866, that at last a satisfactory cable was laid.

CABLE, SHOWING VARIOUS COVERINGS

There are now sixteen cables between the British Isles and North America, owned and controlled by one or other of the two great American companies, the Western Union Telegraph Company and the Commercial Cable Company, the two companies which also own the inland telegraph system of the United States, and partly that of Canada. At this end the Western Union cables are landed at Valentia in Ireland, or Sennen Cove near Penzance; the Commercial cables at Waterville in Ireland.

The first of these cables was laid in 1873, and the latest one, a span between the Azores and Newfoundland, three years ago. This new cable is the world's fastest long-distance cable, capable of transmitting four messages each way simultaneously. It was manufactured and laid by the Telegraph Construction and Maintenance Company, of London, for we still maintain a premier position in constructing and laying cables. The only transatlantic cables controlled by this country are the two worked by Imperial and International Communications Ltd. These cables were until recently under Government control, and were operated by the Post Office.

Four transatlantic cables between France and North America are controlled by the French Cable Company. The Italian Cable Company controls one from Italy, and the German Atlantic Company has recently laid one from Germany.

CHAPTER V

CABLE COMMUNICATIONS

IN addition to the Atlantic cables dealt with in the last article a most important system of cables from the British point of view is that which was developed by the Eastern Telegraph Company and its associated companies. This system connects Great Britain with India, Australasia, the Far East, Africa, and South America, and is the largest and most important cable organisation in the world. The system is concentrated, at this end, at Porthcurno, near Penzance, and the huge amount of traffic dealt with can be judged from the fact that the cables running out eastward from Porthcurno carry some 70 million words a year. The total length of these cables is about 136,000 miles, and their importance to the British Empire is obviously incalculable.

Across the Pacific there are two British cables connecting Vancouver with Australasia, and one American cable connecting San Francisco with the Far East. The British cables were owned jointly by the Imperial, Canadian, Australian, and New Zealand Governments, but have been transferred to private enterprise under the merger scheme. The section between Vancouver and Fanning is the longest cable section in the world, nearly 3,500 miles. Fanning Island is in a coral group in the Pacific; it was annexed by Great Britain in 1888 and the cable station upon it was opened in 1902.

This country is thus linked up with Australasia and the Far East by submarine cables, on the eastern route via the Indian Ocean and on the western route via the Pacific. In addition there is a trans-continental route, mostly overland, via North Russia, largely owned by the Great Northern Telegraph Company of Denmark. Another, via South Russia, largely owned by the Indo-European Telegraph Company of England has recently been closed.

These are the main cable systems, and it is unnecessary here to consider the vast network of lesser systems which spreads out all over the world. The total length of cables now working is about 350,000 miles, of which about 265,000 miles are long-distance cables and 85,000 miles are short-distance cables. Of the long-distance cables about 168,000 miles are British, 89,000 miles American, and the rest various.

Over three-quarters of the cable mileage of the world is owned by private enterprise; the remainder, consisting for the most part of short cables, is owned by the various governments. In this country, as already mentioned, the Government did own two of the older Atlantic cables, and had a share in the ownership of the British Pacific cables and the British West Indian system, but it was decided in 1928 to transfer these cables to a communications company.

This company is the outcome of the report of the Imperial Wireless and Cable Conference, which was published in July, 1928. The conference, which included representatives of the Imperial Government and of the Governments of Canada, Australia, New Zealand, South Africa, the Irish Free State, India, and the Colonies and Protectorates, had been appointed to recommend the adoption of a common policy in view of the situation which had arisen as a result of the competition of the new beam wireless services with the cable services.

The report unanimously recommended a merger scheme to amalgamate in one undertaking all cable and wireless interests conducting communications between the various parts of the British Empire. In 1929 this new company took over the cable and Marconi companies concerned, the British Pacific and West Indian Cables, the two Atlantic cables which are operated by the Post Office, and the Imperial Wireless beam services which, in this country, were also operated by the Post Office.

The chairman and one of the directors of the company must be approved by the Government, and all questions of policy, including alterations of rates, must be submitted to an Advisory Committee comprised of the representatives of the Governments concerned. British control of all the companies must be guaranteed, and in case of national emergency the Governments may assume control of the systems.

This merging of cable and wireless interests for the communications of the British Empire is a most important milestone in the development of electrical communications. It introduced a new era, not only in our communications, but in the communications of the world. The whole idea is looked at askance in some quarters, but when all is said that can be said, it does appear to be based on what we like to think is so eminently British—sound common sense.

We have so far been considering cable developments broadly from the outside, and it may be of interest now to take a rapid bird's-eye view of the technical progress which has taken place since the Atlantic cable became a commercial proposition sixty years ago.

A submarine cable is electrically a large condenser, the conductor forming one plate, the insulation forming the dielectric, and the wire sheathing and water forming the other plate. A cable has therefore a large capacity, and takes a considerable time to charge and discharge, which retards the rate of signalling. This was the first great bugbear of cable telegraphy, and is the principal reason why so far it has been found possible to use telephony only over short-distance cables.

Various devices were, of course, invented to improve matters from time to time, but until quite recently speeds of about 30 words a minute, duplex working, were all that could be obtained. Many improvements were made in the manufacture of cables, but the general form remained essentially the same. The conductor consisted of a central wire of pure annealed copper surrounded spirally by smaller wires to give it greater flexibility, the total diameter being about half that of a lead pencil. Around this, and of about the same diameter, was the dielectric, gutta-percha applied in plastic form; over this was the protective covering of jute, and, lastly, the sheathing of iron wires around which was wound jute, impregnated with a compound of pitch which is more or less impervious to water.

At great depths there is little trouble with the cable, which lies buried in the ooze on the bed of the ocean, but as the depth of water decreases the bottom of the ocean becomes rougher, and troubles arise from the activities of fishing trawlers and the like. For this reason it is necessary for the sheathing of the cable to be much stouter at the inshore ends, so that a cable which weighs two tons a mile in its deep-sea portion may weigh as much as twenty tons a mile near the shore, where its diameter may be increased to as much as two inches.

One enemy to the cable in certain waters is the teredo, or ship-worm. In early days of cable-laying this mollusc bored his way through the covering into the gutta-percha and destroyed the insulation. It was his depredations that led to the protective sheathing being adopted.

The laying of a cable has now reached such a state of perfection that a recent one, which was laid in September, 1928, between Newfoundland and the Azores, a cable-length of 1,341 miles, was working eight days after the expedition had started from Newfoundland.

The ordinary troubles of breaks, partial or complete, in a cable can be dealt with by a repair ship. It was the Great War that brought about more serious disturbance of the submarine cables. In the early days, when the famous German raider, the *Emden*, was abroad she descended suddenly upon the cable station in the Cocos, or Keeling, Islands in the Indian Ocean. Here the Germans severed two of the cables and wrecked the station offices, but the approach of the Australian cruiser, the *Sydney*, sent her off again in hot haste.

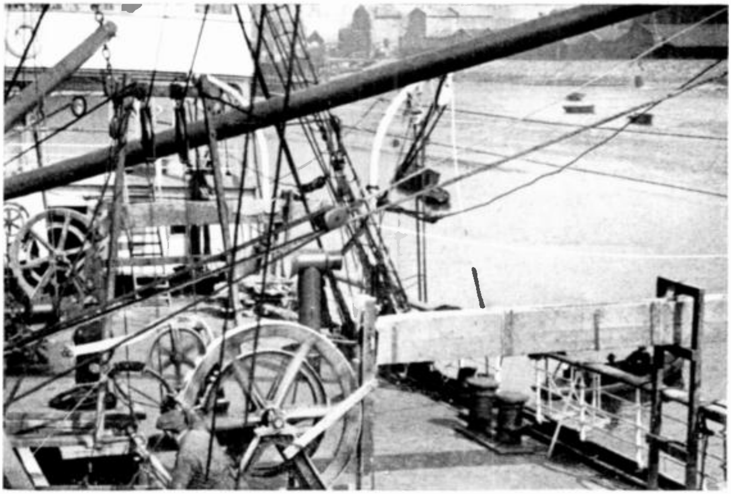
It was an exciting time for the cable station operators. As quickly as possible they picked up the ends of the line running to Perth (West Australia) and effected a splice, so that communication was again made possible.

In another instance of a German sea raid the cablemen succeeded in repairing the damage done by buoying the broken ends of the line on improvised rafts made of planks and barrels, making the connection with ordinary covered wire and thus proving themselves veritable " handy men."

It was not until after the War that the phenomenal advance of wireless made the cable companies sit up and take notice. But they did not sit for long ; they got busy, with the result that cable telegraphy has advanced more in the last seven years than it did in the previous fifty. The pioneer honours for the new type of cable indubitably rest with the engineers of the Western Electric Company of New York, who initiated the first long-distance loaded cable. There were, of course, others to whom great credit is due, notably the Telegraph Construction and Maintenance Company of London, Dr. Wagner of Germany, and last, but certainly not least, the late Oliver Heaviside of England, who had laid the theoretical foundations many years before.

The first long cable was laid by the British Company in the summer of 1924 between the Azores and New York with the co-operation of the Western Electric Company, who provided their loading alloy, which they called " Permalloy." The results exceeded all expectations, a signalling speed of nearly 400 words a minute, simplex, being obtained. Permalloy is an alloy of nickel and iron, and is wound round the core in the form of a thin narrow ribbon. This increases the inductance uniformly throughout the length of the cable, and neutralises, to a great extent, the troubles which arise from capacity. The British Company soon produced another suitable alloy, called " Mu-metal," and the Germans still another, but the American company were the first in the field.

Since 1924 all new long-distance cables have been of this loaded type, and the signalling capacity of each cable has been four or five times as great as would have



Taking Cable aboard a Cable Ship.

Pl. V. C 34.

Cable Storage Tanks.

been the case with the old unloaded type. But these new cables have not been suitable for duplex working at high speeds, as the older ones were at low speeds, and this was, of course, a great disadvantage.

However, the American Company has again come to the rescue with what is called "tapered" loading, which consists essentially of having heavy loading in the middle section, gradually tapering off towards the ends, the final lengths being of the old unloaded type.

The Newfoundland-Azores cable, laid in September, 1928, was of this type, and duplex working at high speed is possible; that is to say, messages can be sent at high speed from one end whilst messages are being received at high speed from the other end.

The general principle employed in duplex signalling is to arrange so that the signals from a station are sent not only over the line, but also into an artificial line, consisting of capacities and inductances with the same characteristics as the real line, and of timing resistances. If the signals were sent from one end over the line only, they would, of course, affect the receiving instruments at that end, so that messages could not be received at the same time from the distant station. But if the signals sent into the line are cancelled out in the receiver by the same signals sent into the artificial line, the receiver remains unaffected, and is capable of responding to signals from the distant station.

Although the older loaded type of cable cannot be used for duplex working, it can be used for multiplex working, first in one direction and then in the other. In multiplex, the cable is automatically connected in turn to a number of transmitters at one end, and, by synchronised apparatus, to the same number of receivers at the other end. With this arrangement a cable which can carry 400 words a minute would give

D

four channels, each capable of dealing with 100 words a minute; and four messages coming in at the same time at 100 words a minute can be much more easily handled than four messages coming in, one after the other, at 400 words a minute.

The latest tapered type of loaded cable can, however, be worked duplex, the messages being sent, too, on the multiplex principle—that is to say, a number of messages can be sent and received at the same time; in fact, the conditions of signalling over the latest long cables now approximate to those of signalling over land lines.

The transmitters used are of the Wheatstone type, arranged to send positive and negative impulses instead of the dashes and dots of the Morse code. In some cases the syphon recorder is still used for reception, but in others, apparatus is used for converting the cable signals into the dots and dashes of the ordinary perforated slip. This slip is then run through a Creed printer, which produces the messages in printed form on a paper tape.

These developments in operation have come about gradually, but the really outstanding advances in working the older cables were due to the introduction of duplex working, the Heurtley magnifier, telephony over short cables, and the regenerator. Heurtley's magnifier increased the size of the received signals, and by its use the speed of signalling was increased by about 30 per cent. The regenerator, which restores the signals to their original condition before passing them on to the next place where the cable lands, thus overcoming to a great extent the effects of distortion and attenuation, increases the speed by about another 30 per cent.

To sum up, it might be said that until seven years ago the outstanding advances had been the introduction of duplex working, the Heurtley magnifier, and telephony over short cables ; whereas in the last seven years we have had the loaded cable, the regenerator, and the tapered loaded cable. The loaded cable introduced high speed working, the regenerator increased substantially the speed of working over the older cables, and the tapered loaded cable introduced high-speed duplex working, and indeed has at last made possible long-distance cable telephony, the " crock of gold " of the submarine cable.

CHAPTER VI

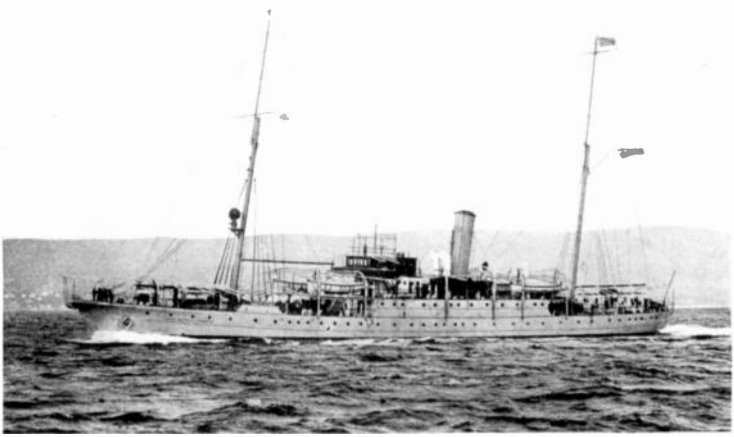
INSIDE A CABLE STATION

WE have traced the history of the cable and followed the growth of its commercial expansion ; it will be instructive now to look inside a cable station and see how cablegrams are transmitted.

No better station for this purpose can be chosen than that of the Imperial and International Communications, Ltd., whose offices are in Electra House, Moorgate, London. It is here that the great volume of cable traffic is dealt with, traffic that concerns Great Britain, her Colonies, Dependencies and Protectorates, the Dominions, the Continent, North and South America, and the Far and Near East. Day and night its instruments are working, receiving and dispatching messages which affect every quarter of the globe.

The Cable Instrument Room at Electra House is the centre of its activities. Here one sees a large staff of skilled operators who, at all points, are handling the volume of cablegrams that pass through their hands, though indeed handling is hardly the right word to use. While an operator is essential both in regard to the despatch and receipt of a message, it is the machines that do most of the actual work. These are " wonder machines " to the layman, though commonplace enough to the expert. The genius of many men such

In the Main Cable Instrument Room at Electra House.



Pl. VI. *D* 39.

The Cable Ship, "Lady Denison-Pender."

A modern cable-laying vessel.

as Samuel Morse, Sir Charles Wheatstone, Lord Kelvin, F. G. Creed and E. S. Heurtley—to mention but a few—has developed cable communication to the highest pitch of efficiency. By means of the devices they invented or perfected, transmitting instruments have come into use that are veritable machines with brains in their mechanism.

Imagine for a moment that we are standing by a table containing some of these instruments. We note first the syphon recorder, already referred to (see page 26), which is receiving a message on a long-distance cable. The delicate construction in detail need not detain us; what we are most interested in is watching a long, slender hollow glass needle through which ink flows, as its curved end traces a continuous wavy line on the paper tape that passes under it. Its curious working is wavy due to the oscillation of a coil of fine wire inside the instrument which is affected by the changes of electric current in the cable caused by the signals being sent, and accordingly communicates its movements through the syphon. This instrument records the signals from the distant station, and simultaneously on another instrument holes representing dots and dashes of the Morse code are perforated on paper tape. This perforated tape passes on, finally to be recorded by a typewriting instrument which, electrically actuated, transforms the combination of perforations into typescript and spells out the message on gummed tape, the latter being swiftly detached by an operator and affixed to telegraph forms ready for delivery. It is all a matter of so many seconds; the machines click the travelling slip of paper on its way, and the operator with deft hand disposes of one finished form and flicks a blank one into place for the reception of the next message.

Neatness and despatch, those two essentials in business, are exemplified to the full in a cable station. There must be no delay: so much may depend upon the speedy delivery of a cablegram. The system of reception and transmission has been carefully worked out to ensure the acme of perfection. Messages that are written out at the counters in the offices below, or that are brought in by messenger boys, are rushed up to the Instrument Room by pneumatic tube, to be sorted and distributed to the transmitting tables. Other similar tubes are discharging messages which have been dispatched from the Post Office or from branch offices of the Company.

In one corner of the room the "zone distributing" system is at work. Here cablegrams for transmission to various points are pigeon-holed and stamped with distinguishing letters—A for London, K for India, and so on—so that no time may be lost in their allotment to operators. Then, a matter of more seconds, the messages are being flashed across the wires to the various points indicated.

The landing point of the Company's cables is at Porthcurno, near Land's End, and from there it is connected by underground lines to Electra House. The wonder of the Cornish station is the system of automatic relays which enable the message transmitted from the head office to be speeded right through along the cable to its destination. In other days cablegrams had to be picked up there by a fresh staff of operators, a method which entailed some loss of valuable time. Another typical station in which the relay system is worked is that in Newfoundland. The bulk of cable traffic that passes through the island, which connects Great Britain with North America, is in transit and not local. It will be understood that there is thus considerable saving in cost by dispensing with manual re-transmission, while the automatic recording results in a minimum of error in regard to the signals themselves.

At intermediate stations where it is desired that the messages received on one cable shall be sorted out and sent on again on several other cables to different points, the incoming signals are caused to effect the perforation of a paper tape. At the point where this occurs the perforated tape has passed out from the receiver, but instead of being now connected with another machine —a " printer "—to be translated into typescript characters, it is carried on to another transmitter which, in turn, passes the signals over another cable.

A cable expert would have much to say in this connection with regard to the definition of signals in transmission, that is, their " sharpness " ; but that is a technical matter that concerns the instrument known as a magnifier or amplifier, which affects the speed of signals along a cable and what may be termed their readability. Another delicate instrument which plays its part in relaying is the regenerator, which operates to correct distortion and avoid attenuation in signal transmission. It is in connection with this device that the synchronome clock has come into use, the purpose of this electrically-controlled piece of mechanism being to ensure a standard speed in the transmission of signals. Such a clock at an intermediate station will automatically record any change taking place in the clock at the original transmitting station.

A new feature of cable work that deserves to be better known is the transmission of pictures, typescript and other documents in facsimile, similar to the process which obtains in wireless and land lines. A description of the latter is given in Chapters XXII and XXIII. Both in the U.S.A. and on the Continent this " picture-telegraphy " by cable has been successfully adopted, and experts regard it as being a feasible form of transmission on long-distance routes.

To watch the several lines of operators at work at their tables in the Instrument Room at Electra House, and realise that scores of messages are being dispatched every minute or so over the world's cables, near and far, is to understand what has been the growth of this method of telegraphic communication from the laying of the original transatlantic cable. Over seventy years have elapsed since a few words from this country were first transmitted across the three thousand miles of ocean to New York, and an answer was received many minutes later.

Those were the pioneer days; the success of the cable-layers thrilled two worlds, the Old and the New. To-day a message from this country reaches the U.S.A. in some fifteen seconds, and the answer to it may be flashed back, allowing for some inquiry to be made, thirty or fifty seconds later.

In a previous chapter note has been made of the principal cables of the world. With particular reference to the station at Porthcurno, it should be stated that cables from here run to Carcavellos, near Lisbon, to Vigo, Gibraltar, Bilbao, Madeira, Fayal, and Harbour Grace (Newfoundland). The Bilbao line mainly covers the traffic with Spain and Portugal. From the others there branch out connections with Malta and Alexandria, these Mediterranean cables (with supplementary ones) linking up communication with the East by means of cables running alongside the Suez Canal and through the Red Sea to Port

Sudan and Aden, whence again are connections with the East Coast of Africa, Bombay, Colombo and Seychelles.

It is a network of cable communication once past the Red Sea. Bombay links up (among other places) Penang and Singapore; Colombo does likewise. And at Singapore lines reach out to Hong Kong, the Dutch East Indies, Australia and New Zealand. From Hong Kong there are cable routes northward through China and extending to Japan, serving the chief Chinese ports.

The whole system is too vast to be enumerated here, but one other cable route may be mentioned, because of its importance: this is the alternative line—a series of cables—the steps of which are as follows: Porthcurno to Madeira, thence to St. Vincent, Ascension Island, St. Helena, Cape Town, Durban, Mauritius, Rodriguez, Cocos Islands, and from the last-named to Fremantle (for Perth), Western Australia. And you get through to all the places above-named from London, or wherever you may be, with ease and a celerity that is nothing short of marvellous. It is, in effect, a communicating machine that even wireless cannot surpass.

The Imperial and International Communications Company's cables total a length of 168,000 miles and, of course, include the South American and Trans-pacific routes. The longest direct cable section in the world, as already noted, is in the latter group, that between Vancouver and Fanning Island, the length being 3,457 miles. Another great stretch of cable (with relays) is to Adelade via Singapore.

And what is the capacity of these high-power cables when it comes to word-transmission? The average, we learn, is 200 paid words every three minutes. In a year, over 70,000,000 words are transmitted, a fairly useful contribution to the world's sum total of electrical communications.

Leaving the Instrument Room now, and putting machine transmission statistics on one side, it is interesting to listen to cablemen as they talk of other features of their work. There are troubles to be faced at times, interruptions to the lines arising from several causes. The most serious of such disasters in recent years was that which occurred in November, 1929, when a submarine earthquake in the Atlantic, to the south of Newfoundland, put nine transatlantic cables out of action for a time. Minor, but still disturbing troubles have originated from steam trawlers, whose fishing-nets, fitted with iron-shod "otter boards," have occasionally dragged over, hooked and broken submarine cables. Then there is the danger of a cable being injured by rocks as it is pulled this way and that by the force of currents; in regions where coral formations exist a specially strong protective armouring to the cable is necessary. Or, it may be, ice has accumulated where the cables land, and this can be as formidable an enemy to the cable as any sharp-pointed rock. For such difficulties repair ships are commissioned, and no time is lost in repairing the damage done.

Of the lighter side of a cableman's life one can learn much from the magazine, *The Zodiac*, which is prepared especially for members of the staff who serve on stations overseas. There is little of what is termed "shop" in this brightly-written paper; it contains mostly social and sporting items of news. One operator records his experiences when hunting big game up-country in East Africa; another has a story to tell of an amusing incident that occurred at his lonely island outpost; yet another sends home a photograph of a pet that he has adopted, a monkey or other animal, with a racy account of its doings.

Electra House produces this publication, and cablemen the world over appreciate it to the full as a link with the home country and a pleasing relaxation from their arduous duties.

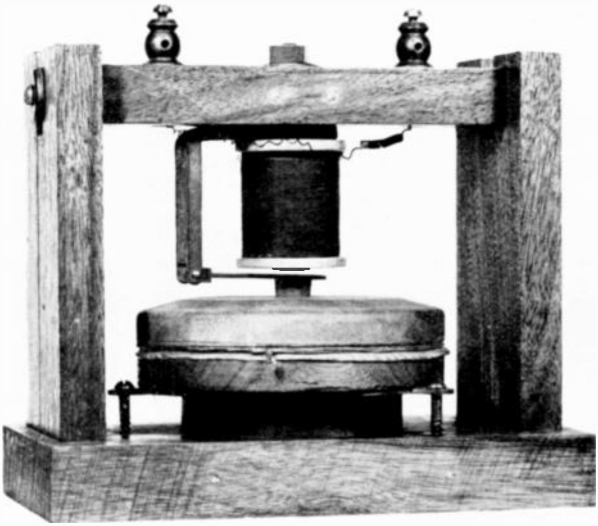
CHAPTER VII

THE BIRTH OF THE TELEPHONE

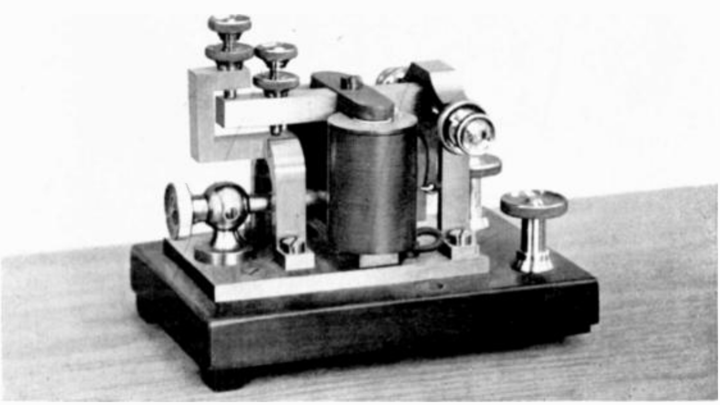
CHARLES (afterwards Sir Charles) Wheatstone, of England, whom we have already mentioned as one of the greatest of telegraph pioneers, was probably the first man to grope for telephony. At the age of nineteen he invented " the enchanted lyre," which was really a stringed instrument connected to a musical box by a long rod. The instrument was set in vibration by the rod connection to the musical box, and as both the rod and box were hidden from view the device was christened " the enchanted lyre," and was well known in London in 1821. Wheatstone undoubtedly saw the possibility of communicating speech, and even dabbled with a microphone, but he was too far off the track, and telegraphy soon claimed him for its own.

The whole idea of telephony lay dormant for nearly forty years, until Phillip Reis, a German electrician, produced a telephone for the transmission of sound. As a matter of fact, Charles Bourseul, a Frenchman, had hit on much the same idea a few years before, but Reis knew nothing of that, and Bourseul had made no attempt to put his idea into practical form.

Reis's transmitter consisted, quite appropriately, of the hollowed-out bung of a beer barrel with the skin of a sausage as the diaphragm. A piece of platinum was fixed to the sausage skin in such a way as to make



Bell's First Telephone.



Pl. VII. *p. 46.*

A Morse Sounder.

and break an electric current when the skin was set in vibration by a sound. The receiver consisted of a knitting-needle on a sounding board, with a coil of wire round the needle. The interrupted current from the line passed through the coil and set the needle and board in vibration, by which means a sound was produced similar to that made at the sending end.

Reis could transmit noises, vowel sounds, and, to a certain extent, music, but he could not reproduce articulate speech. In Germany he is often claimed as the inventor of the telephone, but in other countries the invention of the telephone is invariably linked with the name of Alexander Graham Bell, of Scotland, that land of pioneers.

But as we have found before in considering the birth of other electrical communications, the picture is never complete without a dash of American genius, and we must not pass on now without mentioning the names of two Americans, Royal House and Elisha Gray.

House, before Bell, had patented an electro-phonetic telegraph, capable of operating as a telephone in just the same way as Bell's apparatus; but he never realised the possibilities of his invention—a case like that of Hughes, in wireless, as we shall see later on.

Elisha Gray filed specifications of a telephone on the very same day as Bell, but a few hours later. He brought an action in the courts, but Bell's prior rights were sustained by the Supreme Court; and Gray, though he eventually took out some fifty patents, was completely overshadowed by the Scotsman. Gray's telephone was precisely similar to Bell's, except that he used a constant current to augment the current produced by the vibrating membrane, in much the same way as Edison did later, when he converted Bell's telephone to the form used at the present time.

Bell's father was a great pioneer of lip-reading. His absorbing passion was to bring science to the aid of the deaf, and this passion he passed on to his son, Alexander, who assisted him in his work in Edinburgh. But as at the age of twenty-four the son was threatened with consumption, of which two of his brothers had died, his father took him to America, and it was there that Alexander Graham Bell carried out his great pioneer work on the telephone. His first work was as an instructor of his father's lip-reading system, and it was then that he met Thomas Sanders, whose son was deaf, and Gardner Hubbard, whose daughter was deaf. Bell was so successful with his pupils—in more ways than one, as he later married Miss Hubbard—that Sanders and Hubbard combined to help him financially with his experiments; for Bell was rich in that pioneer's attribute, which we have dwelt on before—lack of money.

Bell's friends all laughed at his idea of speaking over wires, and prospects looked very black indeed until, in 1874, at Boston, he met Thomas Watson, a young American electrician. Watson, now Doctor Watson, is happily still with us, and gave a lecture in London in 1928.

It is not too much to say that, without the assistance of Watson, it is more than likely that Bell's great idea of a speaking telephone would have fructified too late. Indeed it would be as difficult to think of Sherlock Holmes alone as of Bell without his Watson. When first they met, Bell had the idea of a "harmonic telegraph," and took his idea to an electrical workshop where Watson was employed. Watson took on the job, and from that moment the two men were seldom separated by more than a few yards of wire until the telephone had been demonstrated as a practical method of speaking over great distances. In trying to perfect their harmonic telegraph, Bell, who had never let go of the possibility of conveying speech, stumbled up against the principle of the telephone during some tests which they were carrying out, and on that very day Watson constructed the world's first telephone.

These two pioneers worked day and night on their experiment, and on Bell's twenty-ninth birthday, March 3rd, 1875, he was granted "the most valuable single patent ever issued," a patent which gave rise to some 600 lawsuits.

A year later, at Boston, on March 10th, 1876, a seven-word message made history. For the first time a human voice came clearly over a wire. The two inventors occupied rooms on the top floor of a boarding-house in the city. In one room Bell slept, the other was his laboratory. It was in the former apartment that Watson received the telephone call. The voice was Bell's, and the famous message is again reminiscent of Sherlock Holmes: "Mr. Watson, come here, I want you." As the Doctor says, had Bell realised that he was on the point of making history he would have been prepared with a more sounding and impressive sentence.

The harmonic telegraph was then dropped, and as a matter of fact was afterwards perfected by Elisha Gray.

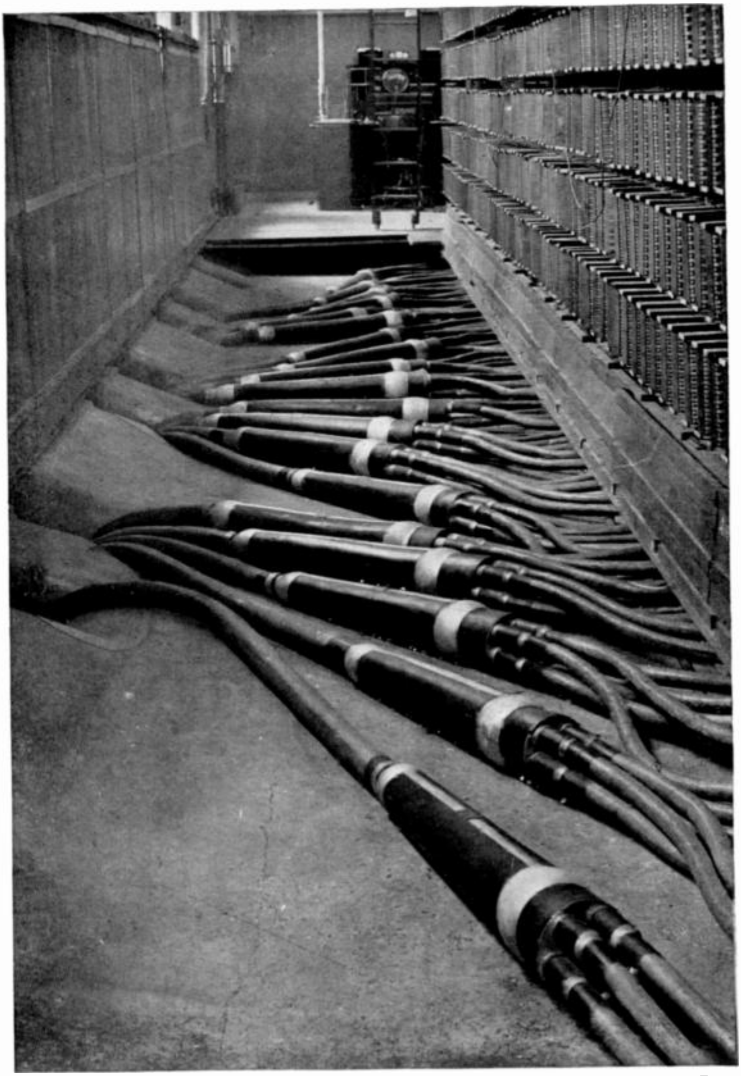
In Bell's telephone the disc which was vibrated by the voice did not, like Reis's, break the electric current, but by cutting magnetic lines of force produced currents in the coil of wire round the magnet. These currents flowed along the wire to the receiver, where the process was reversed, *i.e.*, the currents flowed through the coils of an electro-magnet, thus varying the magnetisation, and so moving the receiving disc in synchronism with the transmitting disc. In this way the sound waves at the sending end were reproduced at the receiving end without the use of a battery, as was required by Reis, and as was introduced in later developments of Bell's apparatus.

In the year 1876 Bell showed his invention in an exhibition at Philadelphia. William Thomson, the great cable pioneer, saw it there, and reported that " this, perhaps the greatest marvel achieved by electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character." Watson did not mind " the rudimentary character," but says that he has never quite recovered from the " homespun " !

Another great electrician, Moses Farmer, of America, saw the apparatus about this time, and Dr. Watson quotes him as saying : " If Bell had known anything about electricity he would never have invented the telephone." How often have we noticed in electrical communications that the pioneers have been led by an "amateur"? But it is not all jam. To quote Dr. Watson again : " Is it any wonder that my memory of those two years seems like a combination of the Balkan War, the rush hours on the subway and a panic on the stock market ? "

It was not, however, what Thomson thought that impressed the public ; it was what Dom Pedro, the Emperor of Brazil, said when he tested Bell's telephone at the exhibition : " My God, it speaks ! " was all he said ; but it was enough to tickle the public imagination and to broadcast all over the world the name of Alexander Graham Bell.

It was nearly a year and a half after Bell had filed his specifications that the first telephone company was formed. The Bell Telephone Association was started in August, 1877, with no capital and four shareholders



PL. VIII. E 51.

Telephone Cables entering an Exchange.

Hubbard, Sanders, Bell, and Watson. Bell had offered his invention to the Western Union Company, who refused it, so he formed a rival concern. Litigation followed eventually, but Bell won. His shares rushed up to 1,000 dollars each. Bell, Watson, and Sanders sold out, and the commercial development of the telephone passed into other hands.

END OF TELEPHONE CABLE

On August 4th, 1922, Bell died in his summer home at Cape Breton, after a life spent in inventing devices to shorten the labours of humanity, and at his burial, as a tribute to the work which crowned his career, all communication was suspended for the space of one minute over the vast network of lines serving the seventeen million telephones in Canada and the United States of America.

We have noted the work of the most outstanding pioneers in the early days of telephony, but as soon as the telephone entered the commercial arena their name becomes legion.

Needless to say, Thomas Alva Edison, the world's most prolific and versatile inventor, was soon to the fore. In 1878 he produced a carbon transmitter, though he was then in the throes of his epoch-making discoveries in electric lighting, and, when he found that his transmitter would be of no use with the existing receiver, he promptly invented a new receiver. About the same time our old telegraph friend, David Hughes, of England, independently invented the microphone, and unfortunately for patent lawyers, but fortunately for the telephone industry, did not patent it. Hughes is rightly accepted as the inventor of the microphone, but, in addition to Edison, there were two Frenchmen whose names we should not omit. Du Moncel seems to have been the first man to recognise that an increase of pressure between two conductors in contact increased the conductivity ; and Clerac, of the French telegraphs, had applied this principle in practice, and had actually lent his microphone to Hughes before even the telephone was invented.

Still, the fact remains that the telephone transmitter as used at the present time is a direct descendant of Hughes' instrument. Francis Blake, of England, made the first outstanding advance, with his carbon button transmitter, and it is of interest to note that at the beginning of broadcasting, seven years ago, an old Blake transmitter was used for some test transmissions on account of its reputation for good articulation.

The Reverend Henry Hunnings, a curate in Yorkshire, produced an excellent granular carbon transmitter about the same time as Blake's invention, and it might be noted by amateur workers generally that Hunnings had not the slightest difficulty in obtaining £1,000 for his invention, which was used commercially for some time in London.

Later on, Michael Pupin, of America, at the beginning of this century, invented the loading coil which went so far to improve long-distance telephony over land and submarine telephony over short distances, and here again we see the hand of the great mathematical physicist, Oliver Heaviside, of England, as loading coils, like the loaded cable, were based on theories which Heaviside had published some years before.

We shall next consider briefly the present state of telephone development throughout the world, but in a more impersonal way, as we should never be finished if we tried to mention the work of the outstanding telephone experts during the last thirty years. There is one name, however, which we should like to mention before passing on, the name of the man who has been a leader on the technical side of telephone development from the earliest days, and to whose genius is so largely due the possibility of transmitting speech over vast distances, a name well known to us all—John Ambrose Fleming, of England, the inventor of the Thermionic Valve.

CHAPTER VIII

COMMERCIAL DEVELOPMENT OF THE TELEPHONE

THE early days of telephony seem now to be bathed in a rosy mist of romantic achievement, but, as a matter of fact, they were mostly spent in a murkier mist in the law courts, a mist which, unfortunately, always envelops the greatest advances of science.

But, fortunately for the writer, as well as for the reader, any attempt to pierce legal mists is quite outside the scope of this book, so we may pass on, in a happier mood, to a short consideration of the development of the telephone from its early days of struggle to its present dominant position in the field of electrical communication.

At the close of 1877, Bell's representative in this country offered a demonstration of the telephone to the Government, but the offer was not accepted. In the same year, however, a number of villages in Germany were connected together by telephone, and the late Queen Alexandra, then Princess of Wales, led the way in England by having her private apartments connected up by telephone to her children's nurseries.

In 1877 the first public exchange was opened in New York, and London followed suit in 1878, with Manchester and Liverpool a few months later. The telephone must indeed have been an assured commercial success in 1879, as it is on record that in that year no less a person than the great G.B.S. was employed as a canvasser by a telephone company in London! Glasgow was fitted in 1880, Paris and Berlin in 1881.

It may possibly surprise the younger generation to learn that the first great undertaking in this country to avail itself of the new invention was a railway, and it will certainly surprise the older generation to learn that the railway concerned was the London, Chatham and Dover.

The first printed list of telephone subscribers was published in 1880, and some of those subscribers still figure in the current list. The only name of an exchange which persists from those early days is the Hop, which was originally situated in the London Hop Exchange. It is now an automatic exchange in Marshalsea Road, and its troubles are not yet over, as a Cockney subscriber recently complained on the telephone that he didn't see how he could dial the first three letters of the exchange, in accordance with the instructions, as there were only two letters in OP!

In 1880, when there were only about 30,000 telephones in America and 5,000 in Europe, our Trunk System was inaugurated by the opening of a line between Leeds and Bradford. Owing to the proximity of large towns in the North, the system developed much more rapidly there than in the South where London remained for another ten years in splendid isolation, with the exception of a single line to Brighton for the convenience, no doubt, of the same wealthy city class which lives there to-day.

In 1892 the trunk system was taken over by the Post Office, and this purchase of the trunk lines by the Government foreshadowed the establishment of a State-owned telephone system. The service provided by private enterprise had proved far from satisfactory, and it was decided that the Post Office should take over the system when the National Telephone Company's licence expired in 1911. The fact that the Government was going to take over the telephones did not, very naturally, imbue the company with any strong desire to spend much money on additional plant or maintenance, so that the Post Office had a stiff up-hill fight for some years after 1912, when the system was finally purchased.

To make matters worse, the needs of War depleted the country of plant and personnel, and the unreal trade boom which followed the War produced, unfortunately, a real demand for telephone facilities. Manufacturers could not cope with demands, the Post Office could not deliver the goods, and the Public wanted to kick something, so they kicked the Post Office, which was as good as kicking anything else. However, the trade boom collapsed, telephone equipment began to roll in, and it was even rumoured that someone had written to *The Times* to say that his telephone had been installed without undue delay. Since then the kicks and delays have been better tuned to the same frequency.

The greatest technical advance made in line telephony since Bell first spoke to Watson has been accepted by the public as a matter of course, but Sir Ambrose Fleming who, as we have already seen, really does know something now about such things, has described the automatic telephone as "the nearest approach of machinery to the human brain."

The telephone of each subscriber on an automatic exchange is provided with a dial, which he revolves by hand for calling-up purposes. The caller dials the first three letters of the automatic exchange which he wishes to call, followed by the four digits of the number required. If he has any trouble he dials "0" and is connected to a manual switchboard by which he can talk to, or at, the supervisor to his heart's content.

The first public automatic exchange opened by the Post Office was at Epsom in 1912, and forty-eight exchanges were in operation before the difficult problem of London was tackled. It was obviously a very different matter to develop a single automatic system to cover a densely populated area of over 300 square miles, but, after exhaustive investigation, it was decided to install plant of the Strowger type, which had proved its worth in previous exchanges, along with the Director equipment, an arrangement specially adapted to meet the requirements of large cities. Indeed, the task which the Post Office undertook in introducing automatic telephony into London was immense, and the Department may well feel proud of its initial success, which augurs well for the future, though it will undoubtedly be a future of hard work, hard knocks, and no prizes.

The first automatic exchange in London was the Holborn Exchange, opened in November, 1927. Six more were added by the end of 1928, when the amount of automatic traffic dealt with in London was well over a million calls a week. The general policy is to install automatics when new exchanges are required due to expansion or replacement, and the conversion of London to automatic working will take some years to complete. Meanwhile, intercommunication between manual and automatic telephone exchanges has been arranged for by the installation of most ingenious apparatus at the manual exchanges. It is satisfactory to find that the percentage of automatic calls established on the first attempt is already nearly as high as for manual exchanges, and that between subscribers on automatic exchanges, when the dialling is carried out correctly, the percentage of wrong numbers is less than 1 per cent., whereas with manual working the percentage is 3.6.

The human element must always be present to a greater or less extent, and it is remarkable how a visit to a busy exchange invariably alters the opinion of a hostile subscriber, especially regarding the efficiency of the operators. The Post Office takes the greatest pains not only in training girl operators, but in selecting the most suitable candidates. In London, only 20 per cent. of those interviewed are considered suitable, which is not much to the credit of the elementary school system as the large majority of those rejected are deemed unsuitable on account of bad spelling, bad writing, or bad speaking.

At the subscriber's end the human element must always be present, and in London this human element has led to many mistakes at the opening of automatic exchanges, especially that of abandoning calls prematurely, and, to a less extent, wrong dialling, but these are only growing pains, and, as experience has already shown, are of comparatively short duration.

The Post Office has arranged that each subscriber shall receive a personal explanation of the use of the dial at his own premises, and every subscriber is invited to visit a working model automatic exchange installed in suitable premises near the real exchange. Amusing difficulties are constantly cropping up, like that of the Hop Exchange already mentioned. For instance, a Hebrew gentleman was recently much annoyed when he failed to get on to the Wimbledon Exchange by dialling the letters V I M.

Telephony in Europe is naturally far more difficult and complicated than in America owing to different languages and multiplicity of control, though from the purely technical point of view long-distance services over land have presented no difficulties since the introduction of telephone repeaters and the thermionic valve. In America, by 1884, it was possible to telephone between New York and Boston, 230 miles; by 1892, between New York and Chicago, 900 miles; and by 1915, between New York and San Francisco, 3,400 miles, with the help of the thermionic valve. London to Bagdad is about the same distance as New York to San Francisco, but there is no service approaching such a distance on this side of the Atlantic.

In 1891 England was connected to Paris, in 1903 to Belgium, in 1914 to Switzerland, and in 1922 to Holland, but a great step forward was made in 1923, when a standing committee, called "The International Consultative Committee," was formed with the object of developing international telephony in Europe. This committee has no executive power, but it has obtained a large measure of agreement on fundamental issues, and has awakened an international interest in telephony.

It is now possible to communicate by line telephony between this country and nearly all countries in Europe. There is no doubt that the lack of long-distance services in Europe was due mainly to the absence of any organisation to advance them, and we are justified in holding high hopes for the future from the rapid advance which has been made since the Consultative Committee got to work.

Throughout the world at the present time there are about 35 million telephones in service, and of these 22 million are in North America, and 11 million in Europe. The number of telephones per 100 inhabitants is about 17 in the U.S.A., 14 in Canada, 11 in New Zealand, 9 in Denmark, 8 in Sweden, 8 in

Australia, 7 in Norway and Switzerland, 5 in Great Britain and Germany, 4 in the Netherlands and Finland, and 3 in France, Austria, Belgium and Argentina.

The percentage rate of increase of telephones in Europe is greater than in North America, and Great Britain's rate heads the list. The number of telephones in Europe is about 11 million (2 million in this country), and in North America twice as many, but in Europe the percentage increase has been 100 in the last 10 years against 50 in North America.

In six of the great cities of the United States, however, the number of inhabitants per telephone is as low as 4, whereas in London, Paris, and Berlin the number in each case is between 10 and 11.

It is not easy to understand why in the United States there should be for a given number of persons four to five times as many telephones as in Great Britain, but the same might be said of motor-cars, in which case the difference is still greater—in fact, about twice as great. There are, of course, differences in temperaments and habits, and in the United States, owing to the higher wage level, the cost of a telephone, though rather higher than it is here, bears a much smaller ratio to the wage-earner's income. It looks, indeed, as if we can never hope to reach the American standard of development unless there comes a radical rise in our wage levels.

When the Post Office took over the system in this country in 1912 there were 700,000 telephones. Ten years later there were 1,000,000, though the war years had intervened, and now there are over 2,000,000.

During the last five years the Post Office has expended many millions of pounds of capital in the development of the telephone service, and the annual profit on the service is now over half a million pounds. Five-sixths of the telephone wires are now laid underground. Taking the last ten years, this country shows a higher percentage of development than any of the chief telephone-using countries in the world.

In the London area especially marked progress has been made in recent years, and there are now 9 telephones per 100 population in the London telephone area, though we are still behind Berlin and Paris with about 12 per 100.

Let us take some further statistics: figures are convincing. In 1923 London had 99 exchanges; in 1930 the number was 150. In the same period the number of telephones (exchange and private) has nearly doubled; while the growing popularity of phonograms is evidenced by this comparison: 1923, 1,909,104; 1930, 3,440,000. Total mileage of single wire provided for subscribers and junctions—1923, 1,555,249; 1930, 2,945,987. There you have a demonstration of the growth of this service in the space of seven years.

The automatic exchange is superseding the older system in more and more areas. Twenty-six per cent. of the direct exchange lines within a ten-mile radius of Oxford Circus are now connected to automatic exchanges. During the next four years another forty-four of the latter will be opened.

A most interesting development has been the institution of what may be termed "community telephoning," *i.e.*, the provision of facilities for enabling a group of people in one place to listen to a speaker in another. This broadcast method, by the use of loud-speakers, is one that is likely to have extensive application in the future.

Every day we have more than three million conversations by telephone, and though we are still a long way from saturation point, even under present conditions, we are now justified in classifying the telephone progress throughout the country as satisfactory, and in confidently anticipating that before long it will rise from satisfactory to good.

CHAPTER IX

WORKING THE TELEPHONE SERVICE

IN the two previous chapters we have studied the history of the evolution of the telephone and the growth of commercial telephony. It will be instructive now to take a glance at a Telephone Exchange, to see how this great national service is made operative. Of the many exchanges dealing with inland work it may be said that one is very like another. Each has its complement of women operators sitting in long lines at their control tables, plugging in as subscribers' calls come through and disconnecting as calls finish. How that important recent development, the automatic system, works, has been touched upon already; there is no need to dwell upon that further as it is a matter of very intricate technical detail.

It is when we come to such an exchange as that which handles Transatlantic and Continental lines that a new point of interest arises. Let us pay a visit to the building in Carter Lane, London, E.C., where this branch of the Post Office telephone service is housed.

It is a busy place. In the main room of the Exchange, when it is in full swing, there will be some 280 girls at work. At one side are those handling the lines to the Continent; on the other are the operators whose switchboards carry the names of provincial towns. Note here the expansion of the Toll system. In 1921 it covered a ring round London with a 30-miles radius from the centre ; now it reaches out for 50 miles. At one corner of the room there is a special section which deals only with Transatlantic wireless messages ; again some whose business is solely with "ship and shore." There are notices up as one passes from point to point, such as "SYDNEY STANDING BY" and "BUENOS AIRES CLOSED." In a bay at one end are the tables for "inquiries," at which a staff of the most expert supervisors and operators is stationed.

To use a common expression, it is a "babel of tongues" around one in the room, but this is a misnomer, for there is no confusion ; each girl is carrying on her duty quietly, methodically and swiftly, holding a brief conversation with a subscriber, maybe, or connecting him or her with the desired line. For foreign transmission, operators are required to be proficient in four languages—French, German, Spanish and Italian. A knowledge of Spanish covers telephonic communication with South America, Cuba and Mexico, in addition to Spain itself.

To take the Continental lines first. In this branch of the Exchange there are 33 countries with which it is linked up. France is first on the list, demanding 35 lines in all, of which 31 run to Paris. Germany is a good second with 23 lines ; Holland has 15, Belgium 14, Switzerland 5, Spain and Sweden 3 each, and Italy 2 ; the total number (some places have only one line) being 103. The London to Paris submarine telephone, as mentioned before, was opened in 1891. Within the last four years cross-Channel telephone transmissions have increased to double the former extent, the new type of cable in use giving up to 21 channels of communication as against three or four previously.

A modern development of the utmost importance in long-distance work has been the improvement in design, and the more extensive use on the 4-wire system of what are known as "repeaters." These are devices which employ thermionic valves such as are used in wireless receiving sets, their purpose being to amplify the attenuated currents received over long lines and thus render the volume at the receiving end of a long line approximately equal to that at the end of a short line. These "repeaters" may be permanently fixed in the line at suitable positions, or placed in a connecting cord circuit which, in exchanges, connect two telephone lines together.

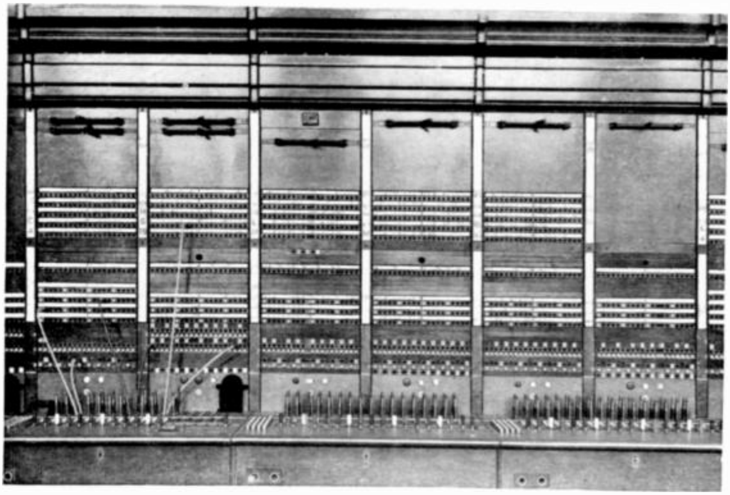
To quote from the latest Report of the Post Office Telephone System, "the fact that programmes of music from Vienna, Berlin and other Continental cities have been successfully transmitted to London over cables with a number of 'repeaters' in series, and then broadcast to wireless listeners, shows the success which has been achieved in the design and construction of cables and 'repeaters.' The range of frequencies required to transmit music effectively is much greater than the range required for speech, and a circuit which will transmit music with such success will transmit an excellent grade of speech."

In the Transatlantic service (turn to the chapter on the Rugby Wireless Station for some details as to this), there are four wireless telephone circuits to New York. One is on a long wave, three on short waves. New York is the transmitting station for the whole of the North American continent, together with Cuba and Mexico, but Canada is to have a direct circuit shortly. Since 1923, when the American Telephone and Telegraph Company successfully transmitted a speech from New York to London, progress has been rapid. At the outset of the public service between this country and the U.S.A. there was an average of seven calls a day for the first year; now the average has increased to between fifty and sixty calls. But on special occasions a day's total will run much higher; on last Christmas Day, for instance, there were over a hundred calls, many of which were seasonable greetings.

You get through to America by wireless at the present moment. In the near future there will be, in addition, direct wire communication, for a submarine telephone cable between London and New York is in course of construction. That it will be extensively used is beyond doubt.

From the point of view of the ordinary user of the telephone it is not cheap to ring up an American subscriber. The original charge for Transatlantic calls was £5 per minute, with a minimum of three minutes (£15). This was later reduced to £3 per minute (minimum £9). At the present time the charge is £2 per minute (minimum £6). That is for transmission between London and New York local areas; there are additional regional charges in both the U.S.A. and the Continent of Europe.

There is a picturesque touch about some of these long-distance calls. Not many months back two aeroplanes were cruising respectively above Buenos Aires, in the Argentine, and Los Angeles, in California. It was desired to establish telephonic communication between these and Sydney, in Australia. The Buenos Aires plane was at a height of 3,000 feet. First of all connection was made by wireless with the land station at Buenos Aires; thence the message similarly travelled to Madrid, from which it travelled by cable to Rugby (via Versailles and London), and finally was



A Telephone Switchboard.

Pl. IX. p. 66.

" Enquiry " at the Gerrard Exchange, London.

sent on from Rugby to Sydney. Conversation, it was reported, continued without interruption for over twenty minutes. In the case of the Los Angeles plane, communication was by wireless to Los Angeles, by cable to New York, and thence by wireless via Rugby to its destination " down under."

The Carter Lane Exchange must be equal to the various demands made upon it. Long-distance calls of an unusual nature may come any day. From the liner *Leviathan* in mid-ocean a business man requested to be put through to a client in a certain town in Chile. The connection at the time was not possible. Would Valparaiso do? came back the query. Valparaiso, fortunately, did serve, so the subscriber, speaking from the ship, was promptly connected with all success.

Incidentally, the telephone service to South America is increasing; since the visit of the Prince of Wales there one may expect to hear that a considerable augmentation in the number of calls has been effected. His Royal Highness himself, with his brother, Prince George, demonstrated the usefulness of the long-distance 'phone when they reached Santiago in their recent trip to South America. They rang up Buckingham Palace about 7,000 miles away, enjoyed a half-hour conversation with the King, the Queen listening-in by means of an extra receiver. The transmission, which was highly successful, was effected in the following manner: the call was routed by land line across the Andes to Buenos Aires; thence it passed via the wireless telephone link to the Post Office receiving station at Baldock, and from this point was relayed through the London Trunk Exchange to the Palace. The return route was similar, but through Rugby instead of Baldock.

Lines of communication are now open to the provinces of Buenos Aires, Cordoba and Santa Fé, to Monte Video in Uruguay, to Santiago, Valparaiso and Vinadelmar in Chile. For these cities there are special hours of service—an hour and a half in the morning and three hours in the afternoon.

Brazil, too, has been linked up telephonically, that country's station being at Rio de Janeiro; and last year an East Indian service to the principal towns in Java was opened. It is possible, therefore, that Dutch may become a compulsory language with operators, in addition to the four mentioned.

The marvels that have been accomplished in wireless telephony in connection with transmission to and from ships have been dealt with in other chapters. But here is another example of the radio service's application. *Belgenland*, a "luxury liner," has set out on a world cruise as these pages are being written. For the convenience of its passengers it has been equipped with apparatus which enables the vessel to be in more or less constant communication with the various land wireless stations throughout the world. It has already spoken with London when nearing Hong-Kong.

Instances might be given, almost *ad nauseam*, of the wide uses to which the telephone service is being applied. One influential business house startled its customers recently with an innovation. The company in question has a number of branches in Great Britain and America. When it was arranged to hold joint meetings in London and several large towns both here and on the Continent, as well as in the States, all at the same time, the telephone was called into requisition. The various points were linked by the Inland and Continental Trunk system and the Transatlantic service, and through the medium of "repeaters" the proceedings at one place were heard simultaneously at all the others. In effect, it was as if one vast meeting was being held, and from a business point of view the value was incalculable.

For public benefit the telephone—by wireless and land line—brought immediate news of the last Test Matches in Australia to this country. Thousands of people day by day watched score-recording boards which followed, minute by minute, the progress of the play. By mechanical movements the operator in charge of each board was able to indicate the position of the game at any moment.

To return to the Exchange at Carter Lane, enough has been said, perhaps, to indicate to the reader the extensive activities of this highly important branch of the telephone service. There are still one or two features of interest to note.

The whole aim of the Post Office Telephone System is to seize upon every development possible that will accelerate the service and tend to give greater satisfaction to its subscribers. At the Exchange itself there will be decided improvements next year. The several sections—Transatlantic, Continental, etc.—will be apart from each other, and the operators will have facilities for making direct, and therefore speedier, connection between lines. Not, indeed, that there is much delay at present.

In the big Trunk Exchange main room there is a central table by means of which the various operators are fed with calls with the utmost despatch. This is known as the " ticket distribution " table. The tickets come up by tube from a room below, are shot out and gathered quickly by girls who slip them, according to their classification, into slots whence they are sped by compressed air tube again to different points of the room. It is rapid work. One second suffices to send the ticket to a near table; in from one to six seconds others are thus served. But under the new system in project this distributing system will be unnecessary.

During the day the busiest time is between 10.0 a.m. and 12.0 noon. Then, as before noted, a staff of about 280 operators will be hard at it in the big main room. The day work begins at 8.0 a.m., when there will be a "skeleton" force on duty, test calls being then made to see that the lines are in working order, and the exchange equipment is also tested. The number is increased at 9.0, and again half an hour later and at 10.0. As fresh girls come on at the different hours they work on a relay system, but each operator puts in 48 hours' duty in a week. The majority work eight and a half hours a day from Monday to Friday, with five and a half hours on Saturday, but a few do a six-day round of duty of eight hours a day.

The Post Office Telephone Service comprises a progressive and enthusiastic body of men and women. It is inevitable that such a service, interwoven as it is with the everyday life of the community, should receive many kicks and few bouquets, but the kickers are seldom those who have taken the trouble to ascertain facts, or even to visit an exchange and see with their own eyes the enormous volume of work with which it deals and the efficient manner in which its difficult task is accomplished.

Pl. X. F 71.

At the London Trunk Telephone Exchange.

Operators on foreign and wireless circuits.

CHAPTER X

THE BIRTH OF WIRELESS

IN 1811, the German scientist, S. T. Sömmering, whom we have already mentioned as one of the great pioneers of line telegraphy, used water instead of wires to conduct an electric current for telegraphic purposes. This was the first time that a practical method was employed for sending telegraph messages by electricity without wires, though other scientists, notably William Watson, of England, in 1747, had suggested the use of earth currents for purposes of communication.

In 1842, Samuel Morse, of America, the great telegraph pioneer, by sinking metal plates in the water on both sides of a river was able to transmit signals across; and at the same time James Bowman Lindsay, of Scotland, was carrying out similar experiments in this country. Many other experimenters, including Willoughby Smith, in England, followed on along the same lines, and others tried using earth currents, but with less success. Many experimenters, too, devised systems of signalling through space without wires by means of electro-magnetic induction. Most prominent amongst these were William Preece in this country, and John Trowbridge in America. These experiments culminated when Thomas Alva Edison installed a technically satisfactory system of induction for signalling with trains on an American railway in 1887, but after the novelty had worn off, the arrangement was found to be in little demand, and the apparatus was dismantled.

All these methods of wireless signalling were based on either conduction or induction, but, in 1879, experiments were made for the first time in utilising what are now called wireless waves. These experiments, which extended from 1879 to 1886, were carried out by David Edward Hughes, of England, whom we have already noted as a pioneer in telegraphy and telephony. Hughes found that an interrupted current in a coil produced, at each interruption, some form of electric waves which could be detected by a telephone in a circuit that included a loose metallic contact, such as the microphone which he had previously discovered.

Between 1879 and 1888 several leading scientists witnessed these "aerial transmissions," as Hughes called them. Preece, Crookes, and Dewar were amongst them. A small coil was used for transmitting, and reception was carried out with a semi-metallic microphone, the results being heard on a telephone receiver. The transmitter and receiver were in different rooms, about 60 feet apart.

Hughes was not satisfied with 60 feet, but later he was able to obtain a range of 500 yards by setting "the transmitter in operation and walking up and down Great Portland Street with the receiver in my hand and with the telephone to my ear." History is silent on what people who met Professor Hughes in Great Portland Street thought about him.

On the 20th of February, 1880, Mr. Spottiswoode, the President of the Royal Society, with the two secretaries, Professor Huxley and Sir George Stokes, came to see the experiments, and after three hours' demonstration announced that they could not agree with Hughes' theory that the results were due to electric waves, as they could all be explained by the laws of electro-magnetic induction. Hughes was so discouraged by this report that he refused to write a paper for the Royal Society until he was better prepared to demonstrate the existence of these waves. Orthodox science had closed the door on the invention of wireless telegraphy, as it has so often attempted to do in the cases of other important inventions.

Present-day amateur experimenters will be interested to read what Sir Oliver Lodge has written of Hughes:

"He was a man who thought with his fingers, and who worked with the simplest home-made apparatus—made of match boxes and bits of wood and metal, stuck with cobbler's wax and sealing wax. Such a man, constantly working, is sure to come upon phenomena inexplicable by orthodox science. And orthodox science is usually too ready to turn up its nose at phenomena which it does not understand, and so thinks it simplest not to believe in."

Hughes died in 1900, and left some £400,000 (which he had made by his inventions) to the hospitals of London. He was a great experimenter, and a lovable man.

There is no doubt that Hughes did not realise that he was using the very waves that had been predicted by James Clerk Maxwell, of Scotland, in 1864, and there was, indeed, another who had similarly used these waves in 1875, Elihu Thomson, of America. Thomson had used the waves and detected their presence at a distance of 100 feet, but he failed to grasp the significance of his experiments, and turned his attention to other investigations.

James Clerk Maxwell, whom Sir Oliver Lodge has described as " one of the essential founders of wireless communication," was born in Edinburgh in 1831. He went up to Cambridge, graduated as Second Wrangler, was elected a Fellow of Trinity in 1855, and carried out his great life work at Cambridge. He was steeped in the work of Faraday, and what he set out to prove, and did prove, was that light and electric waves are identical in nature; in fact, he founded what is known as the electro-magnetic theory of light.

In 1873 he published his epoch-making " Treatise on Electricity and Magnetism." He died in 1879 when he was engaged on a second edition of this work, which has placed him amongst the greatest mathematical physicists of all time. Clerk Maxwell has been described as " a man loved and honoured by all who knew him." His work was by no means confined to the particular line of research which has earned him undying fame, but it is outside our scope to mention his other brilliant discoveries. He not only worked out the properties of these unknown waves, but he gave measurements of their wave-lengths and he predicted that they would travel with the velocity of light. Neither he, however, nor any of his brilliant assistants, was able to give experimental proof of the existence of these waves.

The new theory was received coldly by orthodox science; even so far-seeing an authority as Lord Kelvin refused to accept it, and it was not until 1888 that the theory was experimentally confirmed in Germany by Heinrich Rudolf Hertz, in one of the most brilliant series of experiments that has ever been made.

Hertz was born at Hamburg in 1857. He became a pupil, and later an assistant, of the great scientist Helmholtz. In 1883 he became professor of physics at

Kiel, where he began a study of Clerk Maxwell's theory, and probably became aware of the fact that Fitzgerald, of Ireland, at a meeting of the British Association in 1883, had suggested that electric waves might be produced by the oscillatory discharge of a Leyden jar. In 1885 Hertz was appointed professor of physics at Karlsruhe, and it was there that he carried out his famous series of experiments.

His apparatus was extremely simple. It consisted of what he called "the exciter" and the resonator. The exciter consisted of a spark gap, with metal plates connected to each spark ball by metal rods. At first, the rods were connected to a Leyden jar, and, later on, to the secondary terminals of an induction coil, by which means a spark was caused to pass between the spark balls.

The resonator consisted of a wire bent in the form of a circle, but leaving a small gap fitted on each side with metal balls. He sent out waves with the exciter, and detected their presence by observing the spark which passed across the balls of the resonator. With this simple apparatus, impossible as it may appear, Hertz completely confirmed all that Clerk Maxwell had predicted, and published his results in a remarkable series of papers, between November, 1887, and December, 1889.

It was at once suggested to Hertz that these newly-found waves, which have since been called Hertzian waves, might be used for communicating across space without wires, but Hertz did not know of Hughes' microphonic receivers, and did know that his own receiver was far too insensitive to be of commercial use, so he, too, passed on to other investigations, and the development of wireless signalling was left to other hands.

Sir Oliver Lodge has said that "the enthusiastic admiration for Hertz's spirit and character, felt and expressed by students and workers who came in contact with him, is not easily to be exaggerated." He died at the early age of 37, but to quote Sir Oliver again, "he had effected an achievement that will hand his name down to posterity as the founder of an epoch in experimental physics."

As we have seen, any adaptation of Hertz's work to practical signalling depended primarily on the invention of a sensitive receiver, and it was not long before this was available in the "coherer" which was invented by Edouard Branly, of France.

The principle of cohesion had first been observed in 1850 by Guitard, of France, when he observed that dust particles in electrified air tended to cohere together. Sixteen years later S. Varley, of England, rediscovered the principle, and applied it practically in the construction of lightning protectors. Hughes again used the principle for detecting waves in his experiments in 1879, and in 1884 Oliver Lodge and J. W. Clark applied it for clearing rooms of smoke and other fumes.

In the same year, Calzecchi Onesti, an Italian professor, published the results of some experiments in which he had observed that a heap of copper filings between two brass plates became conductive when subjected to the electrical discharge from an induction coil. About this time, Branly was investigating similar phenomena, and found that the conductivity produced in metallic filings by an electric discharge continued for a considerable time, but would at once disappear if the glass tube containing them was tapped.

Branly published these results in 1891, and probably he did not then realise that the effect was produced by the waves which Hertz had discovered a few years previously. Lodge, however, was quick to grasp the great significance of Branly's work, and in 1894 he repeated all Hertz's experiments with a Branly coherer as detector.

In 1895 Alexander Popoff, a Russian professor, used an aerial wire, connected to a Branly's coherer and a Morse printer, to record lightning flashes. He undoubtedly foresaw that such apparatus might be developed for commercial signalling purposes, as it afterwards was by Marconi, and it has even been claimed that, in May, 1895, he demonstrated the first practical system of wireless telegraphy. Little more, however, was heard of his work until after Marconi's initial successes in practical signalling.

In this country Lodge continued his experiments, and in 1894 signalled by Hertzian waves over distances up to 150 yards, but as he wrote many years later: "I was too busy with teaching work to take up telegraphic or any other development. Nor had I the foresight to perceive, what has turned out to be, its extraordinary importance to the Navy, the Merchant Service, and, indeed, to land and war service, too."

In the United States of America Hertz's discovery was not followed up so quickly as it was on this side of the Atlantic, but as soon as Marconi had demonstrated practical signalling, the American pioneers joined up in the front rank, led by Nikola Tesla (an Austrian by birth), Lee de Forest, and Reginald Aubrey Fessenden.

CHAPTER XI

ENTER MARCONI

WE have seen how, between November, 1887, and December, 1889, Heinrich Hertz, of Germany, astounded the scientific world by publishing the results of his experiments. These results proved not only the existence of wireless waves, but demonstrated all the laws concerning them which Clerk Maxwell, of Scotland, had predicted fifteen years before, and we have seen how these discoveries became at once the subject of experiments in many laboratories throughout the world.

Amongst the experimenters who were quick to pursue the subject was Augusto Righi, Professor of Physics at the University of Bologna, and amongst his pupils was Guglielmo Marconi, who had been born in Bologna in 1874. His father was a wealthy Italian, and his mother was a member of a well-known Irish family.

Marconi was only fifteen years old when Hertz completed the publication of his famous series of experiments. He was at once fascinated by this discovery of electric waves, and he soon had the idea—or, to quote his own words—" I might almost say the intuition, that these waves might, in a not distant future, furnish mankind with a new and powerful means of communication." This may have been the

Marconi with some of his early Apparatus.
Showing spark coil transmitter, coherer and printer.

Pl. XI. *p. 78.*

A Kite that made History.
This kite, flown at Signal Hill, Newfoundland, in December, 1901, carried the aerial with which the first transatlantic wireless signals were received from Poldhu.

first time that Marconi had an "intuition" about wireless waves, but it was certainly not the last. Indeed, this instinctive foreknowledge, which we call intuition, has been one of the most outstanding qualities displayed by Marconi throughout his life work in the sphere of wireless communication, and, luckily for the development of the art, it has, in his case, always been linked with extraordinary determination and unquenchable enthusiasm.

"I could scarcely conceive," he says, "that it was possible that their application to useful purposes could have escaped the notice of eminent scientists." But so it was. The boy had seen in a flash what remained unseen to all those great scientists who had been working on the fringe of the subject for several years. As Sir William Preece said, "They all knew the egg, but Marconi showed them how to make it stand on end."

Marconi commenced, in 1895, at his father's country house at Pontecchio, the experiments which he has continued to the present day. His transmitter was a multiple spark gap as used by Righi, an induction coil, and a Morse signalling key. His receiver was a coherer as used by Branly, the filings being decohered by taps from the hammer of an electric bell, and the local circuit was closed by a relay, as used by Popoff. All the instruments, however, were improved in detail by Marconi, and, towards the end of these first experiments, he broke new ground by connecting one side of the spark gap to an aerial wire, and the other side to earth, thus producing for the first time a practical system of wireless signalling.

Early in 1896 Marconi succeeded in transmitting signals over a distance of two miles, and it is interesting to note that in August of the same year Commander Henry Jackson, R.N., who at that time was working quite independently and knew nothing of the work of Marconi, transmitted messages between warships.

This pioneer work of the late Admiral of the Fleet, Sir Henry Jackson, who rose to the highest rank in the Service and was First Sea Lord in the War, was hidden at the time in confidential reports, and indeed was hardly recognised publicly until 1926, when the Royal Society awarded him the Hughes Medal "for his pioneer work in radio-telegraphy and its application to navigation."

In 1896 Marconi brought his apparatus to England, and on June 2nd applied for provisional protection for his invention. In the following month he got in touch with Sir William Preece, Engineer-in-Chief of the Post Office, whom we have already mentioned as one of the early pioneers in this country. Preece at once recognised the genius of Marconi, and it was largely through his influential support that Marconi was received in this country with open arms, and given every facility for the development of his invention.

Marconi's first experiments in England were made between a room in the General Post Office in London and the roof of a building which was 100 yards distant. Later he worked over two miles on Salisbury Plain before representatives of the Navy and Army, and it is interesting to note that in these early trials he was using reflectors. These were soon discarded as they could only be used with very short waves which were only suitable, with the knowledge then available, for signalling over very short distances. But Marconi never forgot his reflectors, and nearly thirty years later, when conditions had altered, he changed the whole outlook of wireless communication by the introduction of reflectors for his short-wave beam system of wireless telegraphy.

As a result of these experiments in England, the Italian Government became interested and invited Marconi to demonstrate his invention in Italy. This he did, in the summer of 1897, at distances up to ten miles from the shore to a ship, and it was then that he noticed that the range of signalling could be increased by increasing the height of the aerial.

In the same year Professor Slaby, of Germany, who had been an early experimenter with Hertzian waves and who had witnessed some of Marconi's tests in England, carried out experiments near Berlin, using 800-foot aerials held up by balloons. He signalled over a distance of 15 miles, which was greater than any range previously obtained.

In July, 1897, the Wireless Telegraph and Signal Company, which later became Marconi's Wireless Telegraph Company, was formed in London, and wireless entered the commercial arena.

Marconi returned to England and continued his experiments. The East Goodwin Lightship was fitted, and in January, 1899, it was damaged in a gale and reported the circumstances by wireless to a station at the South Foreland Lighthouse, twelve miles away. This was the first time that wireless was used in connection with the safety of life at sea. The first paid wireless message was sent on behalf of Lord Kelvin on June 3rd, 1898, from Marconi's station at Alum Bay, in the Isle of Wight, to his station at Bournemouth on the mainland.

On March 27th, 1899, the Channel was bridged, signals being passed between the South Foreland Lighthouse and Wimereux, near Boulogne. It was then that John Ambrose Fleming, who was well aware of the difficulties to be overcome, had the vision to see further than difficulties, and was not afraid publicly to back the new invention for all he was worth. The following is an extract of a letter which he wrote to *The Times*:

> "Without denying that much remains yet to be attained, or that the same may be effected in other ways, it is impossible for anyone to witness the South Foreland and Boulogne experiments without coming to the conclusion that neither captious criticism nor official lethargy should stand in the way of additional opportunities being afforded for a further extension of practical experiments."

Thirty years later Sir Ambrose Fleming, as he is now known, became President of the Television Society. He could hardly give television a better public backing than that. Again the veteran scientist was not afraid publicly to support a new invention which was shrouded in an atmosphere of "captious criticism." His courage has not aged.

We have seen that the first wireless patent was applied for in 1896 by Marconi, and this was followed in May, 1897, by Lodge's patent for tuning the transmitter and receiver. This latter was the fundamental tuning patent, and was upheld as such time after time in the law courts. It was eventually acquired by the Marconi Company in 1911. On April 26th, 1900, Marconi filed the most famous of all wireless patents, British Patent No. 7777, universally known as the "Four Sevens Patent," which introduced the idea of having at both the transmitter and the receiver a closed tuned circuit coupled to an open aerial circuit similarly tuned. The arrangement was also patented in the United States, and for many years, for all practical purposes, gave the Marconi Company a monopoly of a tuned wireless system both in this country and in America.

Marconi, having bridged the Channel, set himself the task of bridging the Atlantic. Little was then known about how wireless waves travelled through space, and even yet much remains to be known. It was generally held even amongst many of the most eminent physicists, that transatlantic signalling was an impossibility, principally owing to the curvature of the earth. Marconi, like Baird to-day, was not in the least perturbed by the opinions of the most eminent physicists, or anyone else. His idea was to make the attempt ; if it was an impossibility he would fail ; if he succeeded he knew that he could leave it to the same eminent physicists to explain how it had been done.

In 1901 he built the world's first high-power station at Poldhu, in Cornwall. The aerial, in the form of an inverted pyramid, was suspended from four wooden towers. The first masts to be erected were 200 feet high. They were wrecked by a gale, and 170-foot masts were erected in their place. The power was obtained from an alternator driven by a 25-h.p. oil engine. Transformers were used for obtaining the voltage required to charge the condensers, which consisted of glass plates coated with tin foil immersed in oil. Marconi then went across to Newfoundland where, after many troubles, he managed to raise an aerial to a height of 400 feet by means of kites, and he connected the aerial through tuning circuits to a Mercury Coherer, as used in the Italian Navy. On December 12th, 1901, Marconi received from Poldhu a series of the letter " S," the first signals ever sent by wireless across the Atlantic, a distance of 1,800 miles.

In the following month he received signals from Poldhu in the liner *Philadelphia* at 2,099 miles, and it was then that he noticed the daylight effect, that is, the decrease in the strength of signals in daylight, and the fact that this weakening effect was counteracted to some extent by increasing the length of the waves.

Professional experimenters seized on this fact, and the longer the ranges to be traversed the longer the waves they used. It became a sort of obsession, so much so that when amateur experimenters began to take up the subject seriously they found that no Government would allow them to experiment on any of these long waves which were considered sacrosanct to commercial communication. The amateurs were allowed to "play about" on the short waves, as they could not do much harm there. And they did not do much harm. On the contrary, they showed, in 1921, that short waves were quite suitable for long-range communication. The whole outlook of wireless was completely changed.

The wireless amateurs were the pioneers in this great advance, and it is an inspiring precedent for all amateur workers in electrical communication.

CHAPTER XII

FROM COHERER TO VALVE

IN the last chapter we saw how, on the 12th of December, 1901, Marconi signalled across the Atlantic for the first time by receiving in Newfoundland a series of the letter " S," sent from Poldhu in Cornwall. This marked the close of the purely experimental period, and there was now no doubt that wireless telegraphy would prove to be an important addition to existing means of communication, not only with ships, but between different parts of the world.

Up to the time of bridging the Atlantic, the receivers used had consisted of some form of coherer, but in the following year, 1902, Marconi patented his Magnetic Detector which, though it was not suitable for producing the message on a tape, was much more sensitive than any of the coherer types of receiver. With the Magnetic Detector the message was read by buzzing sounds in the Morse Code in a telephone receiver.

Telephone reception held the field for many years, and is still used extensively, especially for signalling with ships. Within the last few years, however, machine telegraphy, which was dealt with in a previous chapter, has been widely adopted for high-speed wireless signalling between land stations. The messages are received on a tape, either printed or in the Morse Code, instead of by sound in a telephone ; indeed, the normal speed of signalling is far too great to be read by ear.

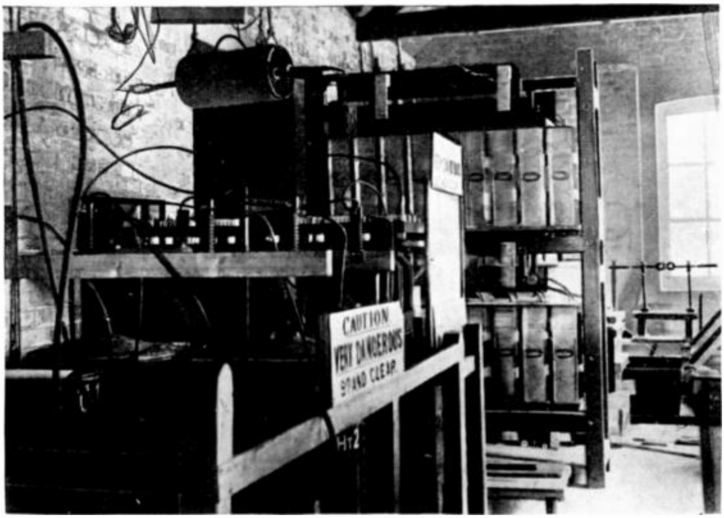
Several forms of Magnetic Detector were invented about this time, but Marconi's type was the only one which came into commercial use extensively. In Marconi's detector, a band of iron wires is drawn by clockwork through a magnetic field. The band moves through a glass tube on which is wound a coil of wire with one end connected to the aerial and the other to "earth." Over this coil there is a bobbin wound with wire, the ends of which are connected to the telephone receivers. The moving band distorts the field, and the received currents have the effect of reducing this distortion. These changes in the magnetic field produce currents in the bobbin of wire connected to the telephones and so produce buzzing sounds in the latter. It is a very robust instrument, and, except for winding up the clockwork, no adjustment is required. This detector was used successfully for many years in ships and stations fitted with the Marconi Company's apparatus.

Other companies in the United States, France and Germany made much use of Electrolytic Detectors, which, like the Magnetic, were used in conjunction with telephones. A common type consisted of two dissimilar metals, one a metal point and the other a large surface, immersed in an acid solution. When at rest, a non-conducting film formed on the point, causing the circuit through the liquid from one metal to the other to have a high resistance. The received oscillatory currents from the aerial disturbed this film, which reduced the resistance, and so allowed currents from a cell to flow through the detector, and produce sounds in the telephone receivers.

These Electrolytic Detectors at their best were more sensitive than the Magnetic type, but had the disadvantage of being more delicate and less easy to adjust.

Historical Marconi Apparatus.

Experimentally tuned circuit (1900) comprising a Leyden Jar condenser, spark gap, and inductance wound round wooden former.



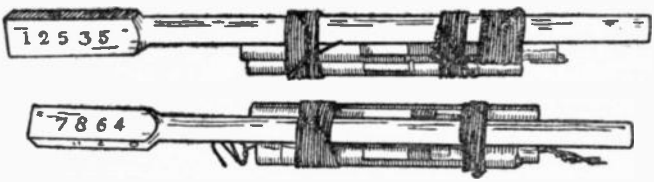
Pl. XII. G 87.

The Marconi Co.'s Wireless Station, Poldhu, 1901.

Early apparatus used in the first trans-atlantic wireless experiments.

The two types of detector, the Magnetic and Electrolytic, held the field until the advent of Crystal Detectors, which are probably familiar to all readers. These detectors were first used in America, by Dunwoody and Pickard in 1906, and they are still used in many broadcast receivers and ship installations.

A Crystal Detector consists of a crystalline material in contact with a metal or another crystalline material, the efficiency of the combination as a detector depend-



EARLY FORMS OF SENSITIVE TUBE RECEIVERS SUPPORTED ON BONE MOUNTS

ing on the materials used. These detectors offer a low resistance to a current in one direction across the contact, and a high resistance to a current in the opposite direction. The alternating currents produced in the receiving circuit can thus be converted into undirectional pulses of current which are suitable for working a telephone. They are said to act as "rectifiers" to the alternating current.

But even before the advent of the Crystals their ultimate supremacy was doomed by the epoch-making invention of Sir John Ambrose Fleming.

In the early eighties of last century, Edison in America, and Fleming in England, noticed that when electric lamps burned out, the glass bulbs became blackened; and both of them investigated this phenomenon. It was not, however, until 1904 that Fleming patented the Oscillation Valve, the action of which was based on the results of those old researches of twenty years before. This was the two-electrode valve, one electrode being the filament of the lamp, the other a metal cylinder inside the bulb. The space between the hot carbon filament and the metal cylinder possesses unilateral conductivity so that, like the Crystal Detector, the Valve can be used as a rectifier, and applied to the reception of wireless signals. It is now in extensive use as a rectifier of alternating current for various purposes. As a wireless detector it was not quite so sensitive as the best crystal type, but it was more stable, and, what was far more important, it initiated a completely new line of investigation for the reception of wireless signals.

The first great advance along this new line, which Fleming had opened up, was made in 1907, by Lee de Forest, of America, who introduced a third electrode in the form of a perforated metal plate or "grid." There were thus three electrodes: the lighting filament, the plate introduced by Fleming, and the grid introduced by De Forest. When a telephone receiver was joined in series with a battery across the filament and the plate, and when the grid was connected to the receiving circuit so that the electric oscillations produced by the signals caused alterations of electrical pressure on the grid, then the space between the filament and plate became conductive, and currents from the battery, flowing across this space, produced sounds in the telephones.

This three-electrode valve, which could be used not only as a detector but also as an amplifier, that is to say, as a means of magnifying the strength of signals, was called by De Forest the Audion.

It is now generally agreed that De Forest's introduction of the third electrode into Fleming's Valve was the most important step in the whole history of wireless signalling, but, in saying that, let us not forget that it was laid down by the Courts in America that this introduction was merely a modification of Fleming's master patent.

The Valve has been aptly called "the modern Aladdin's lamp." Not only has it revolutionised wireless telegraphy, but it has made possible wireless telephony, line telephony over vast distances, wired wireless, talking films, facsimile transmission, synthetic music, television and noctovision. Even this list is not complete, but it is complete enough to show what we owe to the foundations laid by Sir Ambrose Fleming, of England, and Dr. Lee de Forest, of America.

Having thus briefly summarised the development of receivers, it may be of interest to have a look at what was happening on the transmitting side.

When Marconi first signalled across the Atlantic in December, 1901, he used a fixed spark gap and glass plate condensers, which were charged by alternating current through transformers. In smaller installations he was using an induction coil for charging the condensers which were made up of Leyden jars. There were few important developments for the next five years apart from alterations to circuit arrangements, arising from the tuning patents of Marconi and Lodge, which were mentioned in the last chapter. Then came new forms of spark gap.

The first type of spark gap, which consisted of two fixed metal balls, was succeeded by rotary gaps of various designs. By the use of these gaps, the rate of sparking and the duration of the sparks could be controlled, an arrangement which improved transmission, and also improved the note of the signals in the receiving telephones. Many spark installations in ships are still equipped with gaps of this type; others employ a type which was first used by Max Wien in Germany in 1906. This latter type, called the quenched gap, consists of a number of very small gaps in series, the electrodes consisting of metal discs with large sparking surfaces, as opposed to the small surfaces of the rotary type.

In this same year, 1906, Valdemar Poulsen, of Denmark, demonstrated in London a new system of generating wireless waves, based on a discovery made six years before by William Duddell of England. Poulsen's patent, which was taken out in 1903, consisted essentially of using an electric arc in alcohol vapour or hydrogen, in place of a spark. He showed that with this arrangement the radiated waves were much more persistent than with the spark system, and to Poulsen, indeed, must be attributed the invention of the first practical system of continuous wave signalling.

It was adopted slowly, almost grudgingly, in Europe, but quickly received support in the United States, where it was used extensively at many high-power stations. Later, during and just after the War, it was similarly adopted for many large installations in Europe, and, indeed, is still used at a number of stations, but for all practical purposes it may be said that the introduction of high-power valve transmission sounded the death-knell of the Arc.

The Marconi Company, instead of using an Arc, developed a rotary spark, called the Timed Spark System. It was claimed to be a continuous wave system, but it was not used apart from the Company's own stations.

A more serious competitor to the Arc, however, was the high frequency Alternator, which is still used at many high-power stations throughout the world. Dr. R. Goldschmidt of Germany was the first to produce a practical high-power transmitter of this type in 1911. He was quickly followed by several others with various types of Alternators. Foremost amongst these inventors were Alexanderson of America, and Bethenod and Latour of France. With these alternators, the high-frequency current is produced in the aerial without the necessity of having the large condensers and transformers which were required in the old spark installations. The Marconi Company installed Alexanderson Alternators at their high-power station at Carnarvon, but, with that exception, no use was made of the system in this country.

The transmitting position during the War, and for the next few years, was that high-power stations were all being equipped with Arcs or Alternators, but the majority of low-power stations were still keeping to the spark. In ships, the spark system remained supreme, though in America a few ships were fitted with arc installations.

This is the time when wireless telephony began to emerge from its prolonged chrysalis state. With the damped waves of spark transmission, telephony was quite out of the question as a practical proposition, though it was always in the experimental background. Everyone knew that as soon as continuous wave transmission was invented, wireless telephony was bound to follow, but it was several years after Poulsen's Arc patent of 1903 before much success was attained; in fact, wireless telephony was hardly more than a plaything until De Forest added the third electrode to Fleming's valve in 1907.

Experimental work had, of course, been going on continuously with both Arcs and Alternators, and in

November, 1906, R. A. Fessenden, of America, using an Alternator, actually sent telephone messages across the Atlantic. He was carrying out tests in America, and some of the messages were heard at his station at Machrihanish in Scotland.

Neither the Arc nor the Alternator, however, was really suitable for telephony, at any rate not nearly so suitable as the Valve, but even after the Transmitting Valve came in, it took several years before telephony became a practical proposition. Just as war was breaking out, seven years after De Forest's patent, telephony was coming into its own. The War gave a great impetus to wireless telegraphy, which was a going concern and was suitable for coded messages, but it delayed the development of telephony, which was neither one nor the other. Experiments did, of course, proceed, especially in neutral countries and in America; and immediately the War was over, wireless telephony at last came into its own, to rank with aviation as one of the two outstanding inventions of the first quarter of the twentieth century.

CHAPTER XIII

THE SAFETY OF LIFE AT SEA

THE extraordinary public interest which was aroused in this country by Marconi's early experiments was not caused by any golden vision of world-wide communication for commercial gain; it was a product of the salt in our blood, a vision of the sea and of "those who go down to the sea in ships."

Wireless first came to the front as a means for furthering the safety of life at sea. It was then its most important application. It is its most important application to-day. The uttermost parts of the earth were already linked together by the telegraph, but by wireless alone has the earth been linked to the sea.

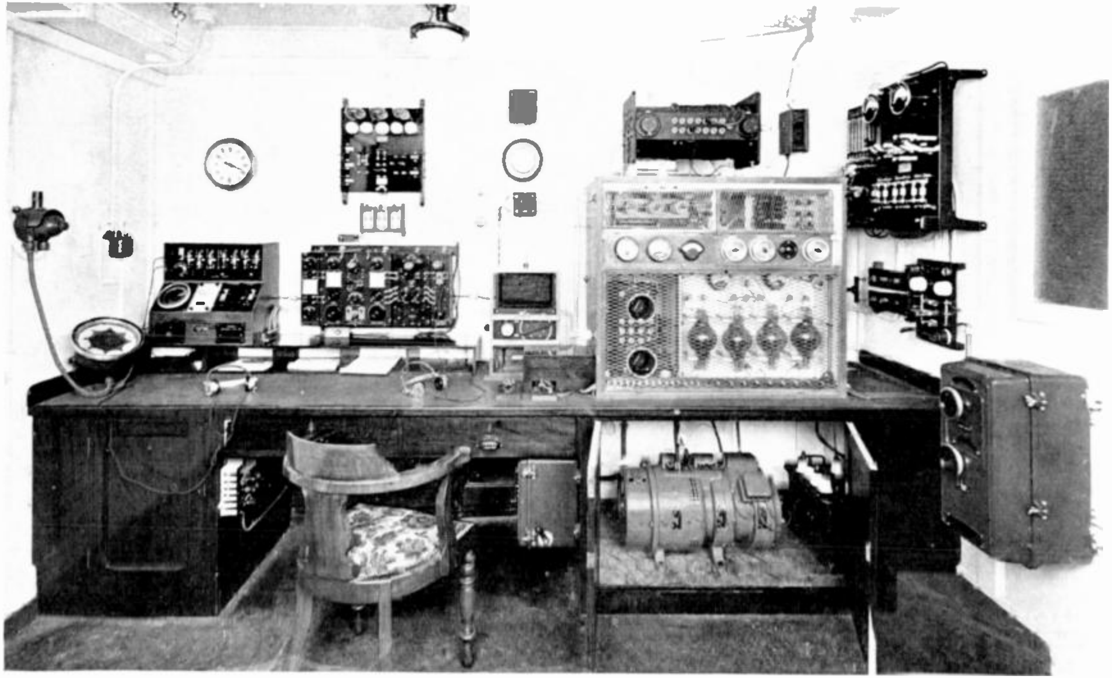
Though the importance from the shipping point of view was immediately grasped by the English people, it did not receive a really striking confirmation until July, 1909, when the liner *Republic* collided with the *Florida* in a thick fog on the high seas. The *Republic* was sinking, and, plunged in darkness, the wireless cabin was splintered; but the apparatus was still workable, and the operator set an example which has been followed without a break by ships' wireless operators ever since. He stuck to his post, and by his calls for help the whole of the passengers and crew were saved. The following day the operator's name was known and honoured all over the world. His name was Jack Binns.

The next startling confirmation was in 1912 when the *Titanic*, with some 3,000 people on board, struck an iceberg on her maiden voyage across the Atlantic. Her signals of distress were picked up by several ships which raced to the rescue, but when they arrived the *Titanic* had sunk, and they were only able to save some 900 persons. Without wireless all would have been lost.

In the following year an International Conference on the Safety of Life at Sea was held in London. An International Convention was signed, but unfortunately, owing to the outbreak of war, it was never ratified by any of the Governments represented at the Conference. Immediately after the war, however, the British Government issued regulations which were on the general lines proposed, and other Governments followed suit with regulations which, on the whole, were less stringent than those laid down for British ships.

Another International Conference was held in London in 1929, and a new Convention signed which came into force in July, 1931. It is a lengthy document but, broadly speaking, its principal provisions are on the lines of the regulations already in force in this country, and where they differ they are better from the point of view of the safety of life at sea.

For the last twelve years it has been laid down that in general all British passenger ships, irrespective of size, and all cargo ships of 1,600 tons and upwards, must be fitted with wireless telegraphy. Exceptions were made as regards certain ships, such as short voyage ships and ships of primitive build, dhows, junks, and the like. This rule is now accepted internationally in



Pl. XIII.

G 94.

The Wireless Cabin, S.S. "Bermuda."

Fitted with the Marconi Co.'s long- and short-wave transmitting and receiving apparatus and direction-finder.

the new Convention, as are the regulations which were in force in this country regarding the minimum technical requirements of the wireless sets installed in ships.

The main ship's transmitter must have a normal range of 100 nautical miles, that is to say, it must be capable of transmitting clearly perceptible signals from ship to ship, over a range of at least 100 nautical miles, under normal conditions and circumstances, the receiver being assumed to be one employing a rectifier of the crystal type without amplification.

There must, too, be an emergency transmitter, and both transmitters must have a note frequency of at least 100. The emergency transmitter must be placed as high above the water line as practicable, in a position of the greatest possible safety, and must be provided with a source of energy independent of the main propelling power of the ship and of the main electricity system. It must be capable of being put in operation rapidly, and of working for at least six consecutive hours. The range of the emergency installation must be at least 80 nautical miles for ships required to keep continuous watch, and at least 50 for all other ships, and whilst the ship is at sea the source of power must be maintained at its full efficiency.

The ship's receiver must be capable of maintaining reception in emergency by means of a rectifier of the crystal type, and must be able to permit of the reception of the waves laid down for the transmission of time signals and meteorological messages.

Within two years from the date on which the Convention came into force every passenger ship must be equipped also with directional receiving apparatus. This is the first time that such apparatus has been made a compulsory fitting. All our large passenger ships are so fitted ; in fact, about twenty-five

may be taken in providing assistance from the shore.

The new Safety Convention recommends that the distress signal should normally be preceded by the Alarm Signal, which is used to put into operation the auto-alarm receiving apparatus in ships in the vicinity. This apparatus is arranged to ring bells in the ship for the purpose of calling the operator to the wireless cabin whenever the alarm signal is received. Auto-alarms have been in use in many British ships for the last few years, but other countries were a little sceptical of their practical utility, and the fact that this apparatus was recognised internationally at the Convention ensures its more general adoption throughout the world. The Alarm Signal consists of a series of twelve dashes sent in one minute, the duration of each dash being four seconds, and the duration of the space between dashes one second.

per cent. of our ships fitted with wireless are equipped with this apparatus, so that the new regulation does not affect us much, but it is most important from the international point of view.

Directional receiving apparatus in a ship enables the operator to obtain the bearing of the ship from any other ship or any shore station which is transmitting wireless signals, so that its importance from the safety point of view is obvious. It is of great assistance to navigation in foggy weather, and has frequently enabled a ship in distress to be located by another ship which is coming to the rescue. When more ships are fitted it will also, no doubt, prove of help in assisting ships to avoid collisions with other ships in a fog.

It is possible that Mr. Baird's noctovision system will prove of great value in this connection later on. With this system a ship will be able to direct a beam of infra-red rays in much the same way as a searchlight, and be able to see, on the screen of its noctovision receiver, objects in the path of the rays.

The most important signal after the distress signal, is the Urgency Signal, which consists of several repetitions of the group XXX. This is used for urgent messages concerning the safety of ships or persons, as distinct from the SOS which is only made by a ship which is in actual danger.

The Safety Signal consists of the group TTT, which indicates that the message following concerns the safety of navigation, or contains information relative to meteorological warnings.

Weather bulletins, gale warnings and navigational warnings are broadcast from our coast stations. Weather reports are broadcast by wireless telegraphy from the Rugby station, and by wireless telephony from the B.B.C. station at Daventry. This broadcasting of weather reports from various stations throughout the world is, in fact, the only use made of wireless telephony in connection with the safety of life at sea.

It is interesting to note that trials are now being made in this and other countries with the transmission by picture-telegraphy of weather charts for the use of ships at sea.

The number and size of lifeboats, and their equipment, naturally occupy a prominent place in the Convention, and regulations regarding their equipment with wireless apparatus are made international for the first time, though there have been regulations on somewhat similar lines for several years in this country. It has now been laid down that where the number of lifeboats carried is more than 13 one shall be a motor boat, and where more than 19 are carried two shall be motor boats. These motor lifeboats must be equipped with wireless telegraphy, the range and efficiency being specified by the Administration concerned.

Since the War it has been the custom here, and in

Pl. XIV. *H* 99.

In the Wireless Cabin, S.S. "Homeric."

Operator adjusting the Marconi Co.'s multiplex telephone receiver used for ship to shore telephony.

several other countries, to inspect ships when convenient in order to see that their wireless installations comply with their licence. All British ships which are equipped with wireless must be licensed by the Postmaster-General, and the Post Office carries out the wireless inspections on behalf of the Board of Trade. For this purpose, inspectors are stationed at the principal ports in this country, and over 3,000 ships are inspected annually. The new Convention lays down that in future a certificate must be issued every year to all ships fitted with wireless in accordance with the Convention, so that ships must be inspected at least once a year.

Regulations regarding the wireless watches to be kept for safety purposes, that is for the SOS signal, are included in the Convention. Each passenger ship which is required to be fitted with wireless telegraphy shall, for safety purposes, carry a qualified operator, and if not fitted with an auto-alarm, shall, whilst at sea, keep watches by means of a qualified operator or a certified watcher, continuously if the ship is over 3,000 tons, or as determined by the Administration if under that tonnage. Similarly, cargo ships, if not fitted with an auto-alarm, shall keep continuous watch if over 5,500 tons, or as determined by the Administration if under 3,000 tons. Between 3,000 and 5,500 tons, they must keep 8 hours' watch a day. On ships fitted with an auto-alarm, this auto-alarm shall, whilst the ship is at sea, always be in operation when an operator or watcher is not on watch, the operator or watcher being on watch at the times laid down by the International Radiotelegraph Convention.

Hitherto watchers have proved to be of little practical use, and the Safety Convention has recognised this by increasing the qualifications required. In future, a watcher must be able to adjust the receiver, read Morse up to 16 code groups a minute, and be able to read the alarm, distress, safety and urgent signals when received through interference.

Looking back at what has already been achieved, there can be no doubt that the advent of wireless has done more towards furthering the safety of life at sea than any other invention with the exception of that of the steam engine.

CHAPTER XIV

SHIPS' COMMERCIAL COMMUNICATIONS

THE communications of ships as affecting the safety of life were considered in the last chapter, but the great bulk of communication consists of what is called "commercial traffic," that is to say, ordinary messages between people in ships and people on shore.

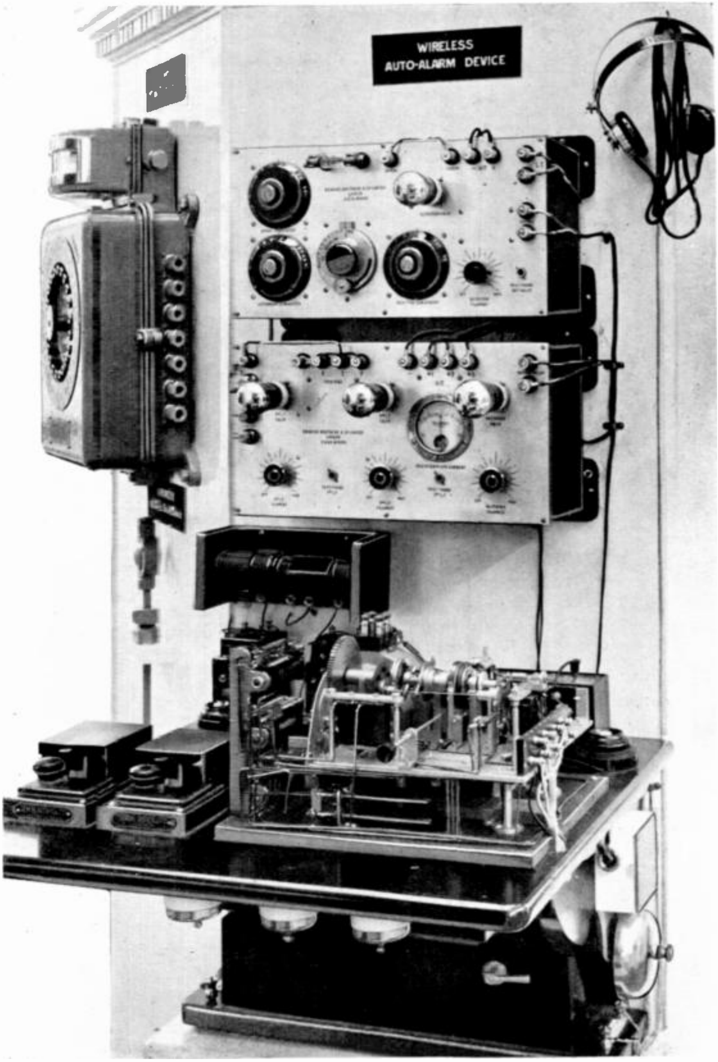
In this country, as in other countries in Europe, communication with merchant ships is organised as an extension of the telegraphic communication of the country, controlled by the same Government department; with us this is the Post Office. In North America, wireless communication with ships is, like the inland telegraphs, controlled by commercial companies. All governments which control these stations subscribe to the regulations as regards tariffs, procedure, etc., which are embodied in the International Radiotelegraph Convention, and though the Governments of the United States and Canada are not tied by these particular regulations, no difficulties arise in practice as the operating companies observe the rules laid down.

The present International Convention came into force on January 1st, 1929, and was the outcome of an international conference held at Washington in 1927. This was the largest and most important gathering of wireless experts ever held. It was attended by 346 representatives from 79 countries, and, surprising as it may appear from its size, it produced first-class results.

The principal station for conducting traffic with ships

MAP OF THE STATIONS IN THE UNITED KINGDOM AND IRISH FREE STATE WHICH ARE USED FOR SHIPS' COMMUNICATIONS

in this country is the Post Office station known as Portishead Radio. It consists really of two stations, the operating station at Burnham-on-Sea, and the transmitting station at Portishead. The messages *from* ships are received at Burnham and telegraphed by direct land line to the Central Telegraph Office



Pl. XV H 103.

A Wireless Auto-Alarm Device.

(Siemens Bros.)

at the General Post Office in London, from which they are telegraphed to their destination. The messages *for* ships are telegraphed to Burnham, where the operators work, by means of land lines, the wireless transmitters at Portishead, so that, though the actual signalling is done at Burnham, the wireless waves are emitted from Portishead. This is called working by distant control, the object being that, by separating the stations, messages *to* ships can be keyed at the operating station, and emitted on certain waves from the transmitting station at the same time as messages *from* ships are being received on other waves at the operating station. In other words, duplex working is attained, and all important land wireless stations are now arranged in this manner.

Portishead Radio communicates with ships on the continuous wave system only, and at present the bulk of the traffic is passed in both directions on wavelengths between 2,000 and 2,400 metres, but during the last two years, short-wave sets have also been used both for transmission and reception. The total annual traffic now approximates to a million and a half words, and the rate charged is 11*d*. a word. Of this, 6*d*. is credited to the station, 4*d*. to the ship, and 1*d*. to the inland telegraphs. The range of working on the long waves is notified as 2,000 miles, but under good conditions greater ranges are frequently obtained.

On the short waves much greater ranges are obtained; in fact, world-wide communication is often possible. Short-wave sets in ships are still in the experimental stage, and only about 200 ships of all countries are notified as being capable of communicating with Portishead on short waves, whereas about 500 ships are notified for long-wave communication.

Long-wave sets have been in use for many years; the problems are solved and the communication is stable; but there can be little doubt that short-wave working with ships will come into its own in due course, as it has already done in the case of long-range point-to-point communication.

All these communications with ships are carried out by hand-keying and telephone reception. Automatic working is sometimes used on the other side of the Atlantic. It has been tried here, and is, of course, quite practicable, but with the present volume of traffic per ship it is not yet an economical proposition.

Messages can also be sent to ships in any part of the world from the Post Office high-power station at Rugby, but ships cannot reply direct, though they can, of course, do so by other routes, e.g., through Portishead if within range, or through foreign stations and thence by telegraph and cable. A charge of 1*s*. 6*d*. a word, including 4*d*. for the ship charge, and 1*d*. for the inland telegraphs, is made for these broadcasts to ships, and at present about 3,000 ships are capable of receiving the long wave used by the Rugby station.

Press messages are also broadcast from Rugby Radio to ships all over the world at definite times every day on both long and short waves.

Wireless messages for ships, in plain language or in code, can be handed in at any postal telegraph office in the country. The name of the station must be specified in the address of messages via Rugby or stations abroad, and in the case of messages at reduced rates for short-voyage ships. In all other cases, however, where the sender is not sure of the appropriate station, he need only insert the word "wireless" on the message form in place of the station's name, and the Post Office will do the rest by routing the message through whatever station is most suitable in the circumstances.

The Portishead station carries the bulk of the traffic to and from large passenger ships, as all these are now fitted with continuous-wave sets, and this traffic is nearly half the total of our whole ship and shore traffic. The remaining traffic is for the most part with smaller ships, and this is conducted through the Post Office coast stations. These stations, as we have already seen, are also used for distress purposes, and are distributed round our coasts so that no ship near the coast can be out of wireless touch with one or more of them; in fact, the necessity of catering for this distress work is the only real justification for incurring the expense entailed in working some of these stations.

The great majority of the smaller ships are fitted with spark installations, the remainder with interrupted continuous-wave sets. The stations, too, used spark sets until recently, but I.C.W. sets are now in use at most of them, and will shortly be in use at all of them, as it is laid down by the Washington Convention that no coast stations can use spark transmission after 1934. This regulation was made in the interest of broadcast listeners, as spark transmission interferes seriously with the reception of broadcast programmes in the vicinity of the station. For the same reason, no new spark sets must be fitted in ships now, with the exception of very small installations, below 300 watts.

The coast stations are situated at Wick, Cullercoats, the Humber, North Foreland, Niton, Land's End, Fishguard, Seaforth, Port Patrick, and Valentia and Malin Head in the Irish Free State. The ranges of the stations are notified as 250 to 300 miles, but much greater distances are frequently obtained.

There are about 3,500 British ships fitted with wireless, but the stations communicate, of course, with ships of all nationalities. The rates are the same as for Portishead, viz., 11*d.* a word, except in the case of short-voyage ships, where reduced rates of 3½*d.* or 5½*d.* are charged according to the service on which the ship is engaged. A press service with ships at half rates is also available, and a letter telegram service is being tried.

It is laid down internationally that, for distress purposes, ships must normally listen-in on the 600-metre wave, and the stations also keep watch on that wave. All calling is therefore carried out on the 600-metre wave. Ships send their traffic also, as a rule, on this wave, but I.C.W. stations use slightly different waves for traffic to reduce interference. The 800-metre and 220-metre waves are also used for ship and shore work.

The Washington Convention has raised the Morse qualifications for ships' operators, the speed of operation required for a first-class certificate being now 25 words a minute, and for a second-class 20 words a minute. The second-class certificate is that normally required, as it is only in the large liners that operators with first-class certificates are necessary. Small ships which are not compelled by law to carry wireless installations may employ an operator with a lower grade certificate, called the "special certificate."

There are some 4,000 operators on British ships, and about 85 per cent. of these are in ships which carry only one operator. Candidates for the post of ship's operator are trained at various privately-owned schools throughout the country, and the examinations for certificates are conducted by the Post Office.

While all British ships fitted with wireless must carry a licence from the Postmaster-General, as already noted, all operators employed must be in possession of the Postmaster-General's certificate of proficiency.

It will be noticed that in the preceding pages no mention has been made of telephone services, but this important aspect of ship and shore communication will be dealt with later.

CHAPTER XV

WIRELESS AS AN AID TO NAVIGATION

WE have seen how Marconi in his earliest experiments made use of reflectors, with the object of increasing range, by emitting the wireless waves in a concentrated beam like a search-light in the direction required, instead of allowing them to disperse in all directions. This arrangement, however, was only possible with very short waves, and as with the knowledge then available such waves were quite unsuitable for communication over long distances, Marconi soon discarded his reflectors and turned his attention to long waves with all-round transmission. But he never lost sight of his short-wave beams, and when, twenty-five years later, altered conditions allowed of the use of short waves for great distances, he started the experiments with his beam system which has revolutionised the whole outlook of wireless signalling—but that is another story.

It was clear from the first that a beam of waves would open up the way to navigation by wireless, as a shore station transmitting a beam in a known direction would allow a ship to obtain its bearings from the station when it came within the beam, that is, when it received the signals from the station. Obviously, however, for this purpose the beam must be very concentrated, which it has only been found possible to arrange for by making use of extremely short waves, far shorter than those used by Marconi in his long-range beam system of communication.

These very short-wave beams have not yet been adapted to navigational purposes commercially, though the Marconi Company has erected two experimental stations in this country, one in the Firth of Forth, and the other at the South Foreland in Kent. The transmitting aerial at these stations is mounted on a revolving carriage fitted with wire reflectors, which allows of the transmission of a rotating beam of waves. Distinctive signals are sent out as the beam passes through the different points of the compass. The ship listens, and makes a note of the strongest signal. The bearing denoted by this signal is the bearing of the ship from the station.

In practice, only very short waves of the order of six metres can be used with this arrangement, and ships must be fitted with special apparatus to enable them to receive such short waves. This is a serious drawback, and the system has not come into general use.

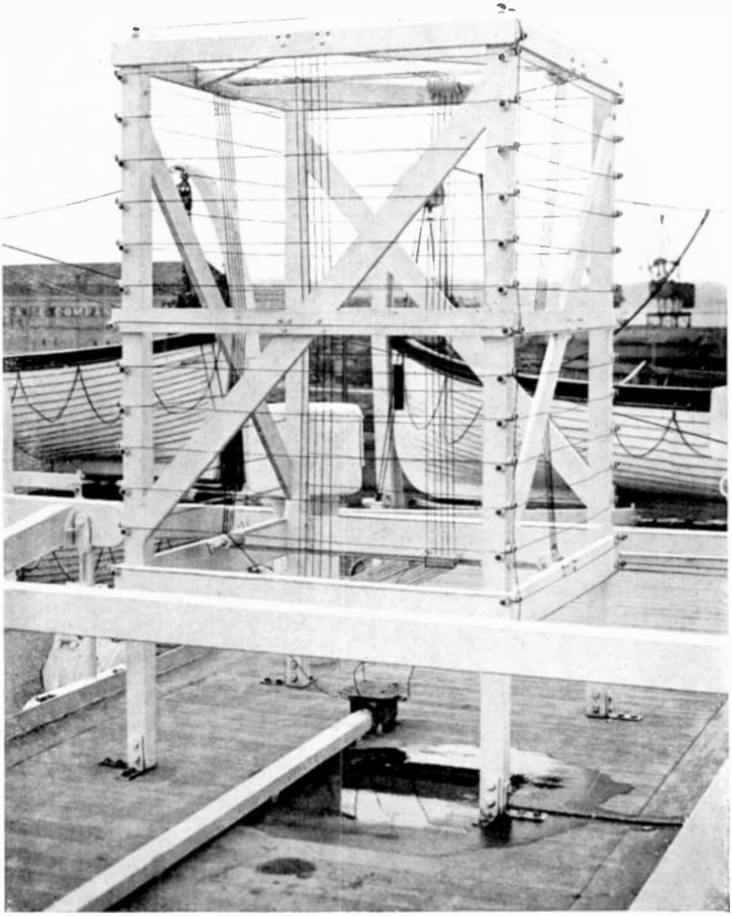
The idea of a rotating beam of waves for navigational purposes has, however, been developed recently by the Radio Research Board on different lines, which permit the use of waves sufficiently long for reception on the ordinary ship's apparatus. A station of this sort was erected by the Government at Orfordness in Suffolk, and is now in operation. The aerial consists of a vertical closed loop, rotating at a uniform speed of one revolution a minute, the waves being emitted in the direction of the plane of the loop. A signal of constant radiation is transmitted throughout the whole period of operation, except when the loop is in a north-south or east-west plane, when characteristic distinguishing signals are transmitted.

The strength of the signal as received by the ship is a minimum when the plane of the station's aerial loop is at right angles to the ship's line of bearing from the station, and a maximum when the aerial loop comes into line with the bearing. The ship's operator starts a stop watch when he hears one of the characteristic signals, and stops it when the emission is heard at its weakest. By a simple calculation he obtains the bearing of the ship from the station.

This is the first station of the kind which has been erected anywhere for ship work, and it is too early yet to say whether the system will come into general use, though it has already proved its worth in connection with the navigation of aircraft up to ranges of about 200 miles. The wave used at Orfordness, as at other beacon stations, is about 1,000 metres.

Stations which emit distinguishing signals as aids to navigation are called wireless beacons, and this particular type of rotating beacon has the great advantage that the ship obtains its bearing by using its ordinary receiving apparatus.

Another form of beacon, which is much cheaper to erect and operate, is now used extensively throughout the world. This is an all-round beacon, that is to say, it emits its distinguishing signal automatically at stated times in all directions. A ship in any position within range of such a beacon can, of course, receive the signals, but unless it is fitted with a directional receiver it cannot obtain its bearing from the beacon. This fact limits the use of such beacons, as the number of ships fitted with directional receivers is small: in this country about 25 per cent. of the ships which have wireless installations. But, as we have seen in a previous chapter, the new International Convention for the Safety of Life at Sea stipulates that all passenger



Pl. XVI. *H 110.*

A Ship's Directional Aerial inside Earthed Screen.

(Marconi Co.)

ships must be equipped with directional receivers, so that the number of ships throughout the world which will be able to make use of these all-round beacons will be materially increased.

Twenty of these all-round beacons, operated by Trinity House or local authorities, are already in operation in this country, and more will be erected in course of time.

Ships which are fitted with directional receivers can obtain bearings up to ranges of between 50 and 100 miles from these stations.

The stations at Spurn Head and Liverpool also transmit submarine sound signals which, in conjunction with the wireless signals, enable a ship to calculate its distance as well as its bearing by allowing for the difference in the speed of travel of the sound waves and the wireless waves. Sound waves in water travel at a speed of about one nautical mile in one and a quarter seconds, whereas the wireless waves reach the ship, for all practical purposes, instantaneously. The advantage of having such combined signals is obvious, but these stations, which are called synchronous beacons, are, of course, more expensive to install and to operate than the simple wireless beacons.

Another type of synchronous beacon is used by the Clyde Lighthouse Trustees. In this case wireless telephony is used, and the words, "one," "two," "three," etc., are broadcast from a gramophone record in conjunction with the fog sound signal in such a way that when the sound of the signal coincides with a number heard on the wireless apparatus that number is the number of miles of the ship from the fog beacon. The Trustees already make use of wireless for controlling the operation of acetylene fog guns from a distance, and this is, indeed, the only application of wireless for this purpose that has yet been put into commercial operation.

These all-round and synchronous beacons are only of use for obtaining bearings to ships which are fitted with directional receivers.

There are three main designs of directional receivers at present in use, viz., the fixed double loop, the rotating double loop, and the single loop.

In the fixed double loop system, the aerial consists of two vertical loops in planes at right angles to one another. The operator rotates a coil in the receiving set and by this means varies the strength of the signals heard in the telephones. The direction from which the signals are coming is determined from the position of the coil when the signals sound weakest.

In the rotating double loop system, the aerial is similar, though smaller, and capable of being rotated mechanically from the wireless office. The connections, too, of the loops to the receiver can be reversed in the wireless office by a simple switching arrangement. The operator listens to the signals and rotates the aerial until he finds a position where reversing the connections does not affect the strength of the signals. The direction from which the signals are coming is determined by this position.

In the single loop system, the aerial consists of a small single loop which is capable of being rotated mechanically from the wireless office, and the direction from which the signals are coming is determined from the position of the loop when the signals sound weakest.

In all cases, the bearing obtained is the bearing of the station relative to the direction in which the ship's head is pointing at the time, and depends for its correct interpretation on the accuracy of the compass reading when the observation is made. There is no real difficulty in this, and in the latest sets it is arranged for automatically, so that the operator reads off the required bearing on a scale with no need for calculation. A new system with a small rotating double loop aerial, electrically driven, is being tried, the bearing being given visibly by a pointer on a scale.

Bearings obtained with any of these systems are, under normal conditions, accurate to within two degrees, which is all that is required for navigational purposes up to ranges of about 100 miles. When conditions are not normal the operator is aware of the fact from the character of the signals received, and in such cases reports the bearings obtained as being unreliable. If, however, the ship is in a position such that the signals received from the station pass along the coast line or over much intervening land, the observations may be unreliable, and the operator may not be aware of the fact, though it is seldom that he will be so vague as to the position of the ship as to place reliance on such bearings.

Ships fitted with directional receivers can obtain bearings from other ships and from ordinary coast stations. In such cases it is usual for the ship which requires the bearing to ask the other ship or coast station to send its call sign continuously for a minute, which is ample time for obtaining a bearing. In this country the coast station makes a charge of 5*s*. for each one-minute period of sending. As already mentioned, about twenty-five per cent. of our ships fitted with wireless are now installed with directional receivers.

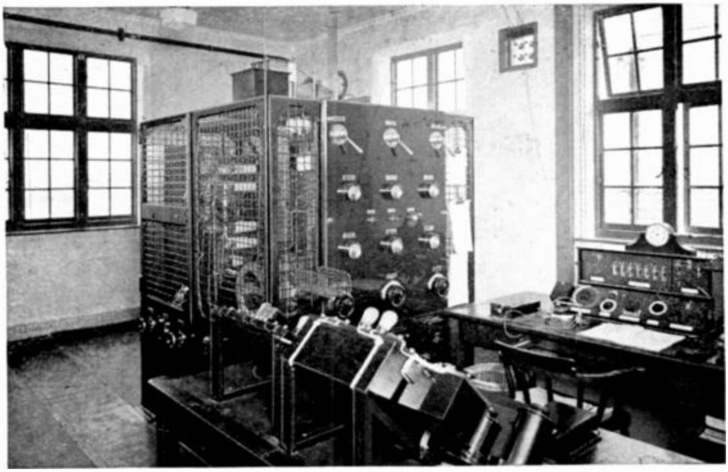
All these methods by which a ship can obtain bearings, except in the case of obtaining bearings from the Orfordness rotating beacon, necessitate the ship being fitted with a directional receiver, and, as we have seen, the great majority of ships are not so fitted. To meet the case of these ships to some extent, a number of coast stations throughout the world are fitted with directional receivers for the purpose of taking bearings. In this country the stations at Wick, Cullercoats, the Humber, Niton, the Lizard, Portpatrick and Malin Head are so fitted. These stations are carefully calibrated every year, and those sectors in which bearings may be unreliable, due to the effects of coast lines or intervening land, etc., are published for the information of shipping. In any case, the operator at the station informs the ship if he considers that there may be any doubt about the accuracy of the bearing, so that unless the ship is told to the contrary it may be confident that the bearing given by the station is accurate to within about two degrees.

The procedure is that the ship informs the station that it requires a bearing, and then sends its call sign continuously for one minute. The station observes, with its directional receiver, the direction from which the signals are coming, and transmits this bearing to the ship. The stations use the 600-metre wave for this work, with the exception of the Lizard which uses the 800-metre wave, and a charge of 5*s*. is made for each bearing given. This service is especially useful in foggy weather, and these stations give about 10,000 bearings to ships every year.

So far, we have considered the ship as obtaining a bearing from one station only, but it is obvious that if it is placed so that it can obtain reliable bearings from two or more stations within a very short space of time, it can fix its approximate position from the intersection of these lines of bearings on the chart.

With regard to aircraft, the advantage of obtaining bearings from ground stations is obvious, and all

The Portishead Transmitting Station.



Pl. XVII. H 114.

Transmitting Instruments, Main Receiver and Directional Receiver, N. Foreland Station.

important aerodromes, such as Croydon, Lympne and Pulham, are equipped with directional apparatus. In the aircraft there are serious difficulties in fitting directional receivers, as space is so limited and the personnel have so many other things to attend to. Efforts are being made to get over these difficulties, but at the moment aircraft have to rely principally on bearings obtained by ground stations.

There are several other aids to navigation which utilise wireless apparatus, notably the Leader Cable and the Fathometer. There is also an important one in process of development, viz., Mr. Baird's Noctovisor.

The Leader Cable is a method of guiding ships in or out of harbours, or through narrow waters. It consists of an alternating current submarine cable laid along the course on which the ship should steer. The ship is fitted with two special receivers, one on either side. When the ship is directly over the cable the strength of the signals received by induction from the cable in each receiver is the same; but when the ship is not directly over the cable the signals in the receiver nearer to the cable will be stronger than in the one farther away. The correct course is, therefore, that on which the signals are received at the same strength in both receivers.

The Fathometer, which was originally invented by Fessenden, whom we have noted as one of the great American pioneers of wireless, is the latest method of taking soundings from a ship. The rate of travel of sound in water is known, and if a sound is transmitted from the bottom of the ship it will be reflected back from the bed of the ocean. In the Fathometer this reflected sound is amplified by valves, and is made to operate apparatus so that the depth of water can be read directly off a scale. It is a most ingenious arrangement, and will doubtless be used extensively in the future.

Mr. Baird's Noctovisor depends on the fact that infra-red rays, which are invisible, can penetrate fog far better than visible light rays. A ship equipped with such apparatus could direct a beam of these infra-red rays, and be able to see on the screen of its noctovision receiver objects in the path of the rays, such as the navigation lights on another ship or the light from a lighthouse or lightship, and thus ensure a greater degree of safety during its passage in difficult atmospheric conditions.

Experiments are also being made with beams of extremely short waves, and the results recently obtained seem promising. At a demonstration given by the International Telephone and Telegraph Company in March, 1931, beams of waves of only about seven inches long were used for wireless telephone communication across the Channel at Dover, and it is possible that such beams may be developed as an aid to navigation, in addition to other purposes.

CHAPTER XVI

AT A COAST WIRELESS STATION

THE part that wireless telegraphy and telephony play in regard to ships at sea is one of the most important features of wireless communication. To the popular mind it is represented mainly by the SOS distress signal. From time to time a maritime disaster, in which wireless is the means of effecting a rescue and so saving scores of lives, brings this prominently before our notice. We read of the heroism of an operator who stands loyally by his set in a sinking vessel, sending out signal after signal in the appeal for help. But this is only one instance of the invaluable aid that wireless is to the shipmaster. To such a high pitch of efficiency has the service been raised that nowadays every ship, with the exception of small craft, is, or can be at will, linked up with land communications.

To effect this means of safeguarding shipping a number of coast wireless stations have been established round Great Britain and Ireland. To enumerate them once more, these comprise Wick, in the north of Scotland; Cullercoats, Humber and North Foreland, on the east coast of England; Niton and the Lizard, on the south; Land's End, Portishead, Fishguard, Seaforth and Portpatrick on the west; with Malin

Head and Valentia respectively at the north and south of Ireland. Portishead is for traffic only; the Lizard is solely a DF (direction-finding) station, giving bearings to ships; the rest combine distress watch with traffic, and some also with DF work.

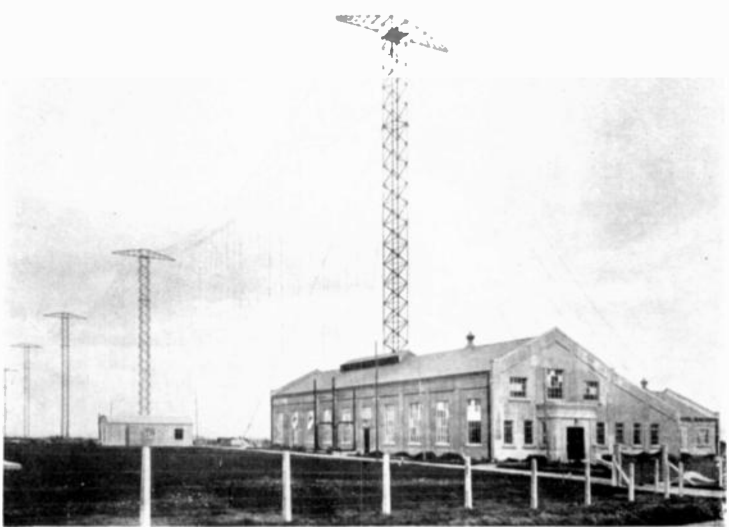
To understand fully the activities of a coast wireless station and its importance in relation to sea-going vessels, we cannot do better than pay a visit to a typical centre. Here, as we study the apparatus employed and note the various duties of the operators, we shall see what takes place in everyday work. For the purposes of this chapter a glance over the North Foreland wireless station at Broadstairs will be sufficient.

The North Foreland station is concerned with traffic and distress work, and it is one of the busiest of them all, owing to the large number and varied character of the craft using the Narrow Seas. No ship off our south-east coast that is fitted with wireless escapes its notice; it stands on the bleak, wind-swept headland like a policeman on point duty in the street, recording the movements of vessels, sending them messages of great, or of little, urgency, and advising them from time to time on matters affecting navigation.

As a rule, every ship, British or foreign, that is able to do so, communicates with a coast station in passing, whether messages are dispatched or not. These reports are recorded in a book kept on the operator's table, which is used for following the passage of ships. Lloyd's regard this service as highly valuable, as it assists them in the compilation of their daily lists of ships.

All these stations, excepting Portishead and Lizard, keep their permanent watch on the 600-metre wave,

The North Foreland Wireless Station.



Pl. XVIII. *f. 110.*

The Marconi Co.'s Beam Station, Dorchester.

Power house building and offices, with 270-ft.-high masts.

that being the wave on which signals of distress are sent. All messages received from ships by wireless are telegraphed to the appropriate telegraph office by the ordinary landline system, while messages intended for ships are handed in at any telegraph office, in the ordinary way, telegraphed to the appropriate coast station, and thence sent by wireless telegraphy to the vessels in question.

To return to the North Foreland station, let us glance at its equipment and, so far as is possible, follow the operators at their work. Situated, as stated, on the headland by Broadstairs, the station comprises a one-storied building in which are housed the transmitters, batteries, motor-generators, receivers and other necessary apparatus. The staff consists of an officer in charge, eight operators and a "handy man."

Outside the buildings one sees two steel towers,each 120 feet high, and 4 steel masts, each 40 feet high, for supporting the aerials. Inside the station there is the usual apparatus, including the motor-generators, the main transmitter (a 1½ kilowatt valve transmitter), tuning-coils (mounted on American white wood of high insulating quality), an emergency transmitter, and two sets of batteries. Then there are the main switchboard for distributing the power, the battery distributing board, the control panel fitted with automatic starter, etc., the receiving apparatus, both all-round and directional, and the landline apparatus.

Now for the operators at their work. The one on wireless watch keeps a careful log, and the rate of logging is about one entry a minute. This operator, too, records any breach of the International Convention which is committed (foreign ships especially are liable to such slips), and the matter is taken up by the Post Office with the administration or company concerned. Attention is never relaxed while on duty; the headphones are never taken off, for there is always the possibility of an SOS signal. To all such regulations rigid adherence is imposed, as otherwise, indeed, a proper marine service would be impossible. A second operator on watch attends to the landline, the telephone and the wireless apparatus generally.

The International Morse code is used for signalling. The "Q" series (so styled because every code word starts with that letter) is the code common to all countries for operating signals. Every likely question and piece of information is covered by this code, which all coast wireless stations use, from Scandinavia to Japan, and which is carried by every ship subject to the regulations. The operators must be proficient, up to a certain standard, in French and German, so as to facilitate working with foreign ships.

What are the principal features of an operator's daily duties? Without insisting upon any order of importance, these may be classed as follows: The distress watch and the working of traffic; the "logging" of ships' movements, as they report to the station in passing, the name and the position, etc., of each vessel thus communicating being notified to Lloyd's; the broadcasting of navigational warnings, which include information as to expected gales, the alteration of seamarks, and the discovery of derelicts and other menaces to ships. A ship is expected to report promptly when any danger to navigation is observed; this news is broadcast by the station, which also informs the following authorities: Lloyd's at London and Dover, the Underwriters at

Glasgow and Liverpool, and the Hydrographer of the Navy, at Whitehall, London. The last-named advises the station as to whether the broadcast is to be continued, and, if so, for how long, and he may initiate broadcasts as necessary. Such authorised broadcasts are carried out at scheduled hours by coast stations; at North Foreland, for instance, the times are 8.0 and 2.0, a.m. and p.m.

Similarly, Niton (in the south) informs ships leaving or entering Southampton, as Seaforth does with ships in the Mersey, and Humber with ships in the Humber. The other stations broadcast at scheduled hours.

Portishead station is purely a traffic station and is fitted with special long-range apparatus on both medium and short waves. It collects weather information, too, from selected ships for use at the Meteorological Office in connection with weather forecasts.

Weather messages are of considerable importance to the navigator. Every day at 2.0 p.m. a weather message is sent out from the North Foreland station, as is the case, of course, with others. This message is received from the Admiralty Hydrographer or the Air Ministry's Office in London. Rugby Radio also broadcasts similar messages, and the B.B.C. station at Daventry broadcasts weather messages to ships by wireless telephony. Abroad, in Germany and the U.S.A., weather broadcasting by means of picture telegraphy is being experimented with; eventually, therefore, it is possible that every shipmaster will be saved the trouble of preparing his own weather charts, based on the information sent to him, and will have such charts transmitted direct to his receiving instrument.

Another form of wireless communication is that of time signals. These are broadcast daily all over the world in order that navigators may check their chronometers. In Great Britain a time signal broadcast is made from Greenwich via the Rugby Wireless Station twice daily, at 10.0 a.m. and 6.0 p.m.

The SOS signal already referred to (see page 99) has priority over all other transmissions. According to the regulations, all stations that receive it must instantly cease transmissions which are capable of interfering with the distress call or messages, and must listen on the 600-metre wave used for this particular call. Similar rules apply to the wireless telephony call, the spoken signal for which is the word " Mayday " (M'aider).

We will assume that such a signal has been received at the North Foreland, and as the SOS is in its area that station takes control of it. Every possible detail of the disaster that is gleaned is at once reported, and the Ramsgate coastguard is held responsible for taking such steps as are necessary, informing the coast station as to what is being done. Lloyd's at London and Dover are notified, as well as the Underwriters in Glasgow and Liverpool, having regard to the question of insurance. Notification is also sent to the Naval Authorities, and to the Admiral in command at Chatham.

While all these matters are being attended to, wireless messages are sent to the ship in distress, giving particulars as to the steps that are being taken for relief, and ships in the vicinity are kept in touch with the situation. It often falls to the operator to select the ship which appears to be nearest to the vessel in distress and inform the master to that effect. It is his duty to advise only, be it noted; he has no authority to order a shipmaster in such circumstances; but the new Safety Convention lays down that no shipmaster shall refuse to respond to an SOS call.

Another SOS signal that may be heard at any moment is that of an aircraft. Very much the same course of procedure is followed, the air authorities at Croydon and elsewhere being promptly notified of the occurrence.

The SOS signal means that the ship itself is in danger. For minor distress needs the "Urgency" signal is employed. This covers less important casualties as "man overboard," "in need of a tug," and such-like. Similarly in the case of aircraft the signal "PAN" is used, both in wireless telegraphy and telephony. This "Urgency" signal takes priority over all other communications with the exception of the SOS distress signal, and it is incumbent upon all ships, aircraft or coast stations on hearing it to avoid interference with the message.

Another signal that must be regarded as taking priority over ordinary communications is the "Safety" signal, TTT, which is used for important navigational messages, etc. (see page 100).

Apparatus for directional wireless receiving, by means of which the bearing of a wireless transmitting station or a ship can be defined, is being widely adopted by sea-going vessels. As noted elsewhere, it is a feature of all large passenger-carrying ships and a number of the bigger cargo-boats.

Every coast wireless station in Great Britain is able to send signals whereby ships fitted with directional receivers may obtain their bearings. The procedure has already been described. The ship asks for transmissions for a bearing; the station sends its call sign for one minute, and the ship takes the bearing.

CHAPTER XVII

POINT-TO-POINT WIRELESS

WE have discussed the applications of wireless signalling to the communications of ships in some detail, as in this particular province it has no competitor for communications beyond visual range, and its applications become, therefore, not only important but unique.

The same cannot be said when we turn to communications between places on land, because, as we have seen, all great centres of population throughout the world were linked together by telegraphy, and many of them by telephony, long before Marconi introduced wireless signalling as a practical means of communication. The field was already well exploited and the newcomer had to show clearly in what ways it might be superior to the old-established systems before it could hope to receive adequate financial backing.

At first, progress was slow, and it was said that wireless might be useful for land communications in out-of-the way parts of the earth where the ordinary line telegraph was impracticable—in fact, in those places where it was pretty obvious that it could not possibly pay its way; so that was not much help. The War Office saw at once the great potentialities of wireless for point-to-point working in military operations, and sent out sets to the Boer War which

Pl. XIX. *f 126.*

Transmitting Hall of the Marconi Co.'s Beam Station, Dorchester.

Used for transmission to U.S.A., S. America, Egypt, Japan and Far East.

was then in progress. The whole thing, however, was so much in the experimental stage in those early days that results were disappointing, though enough was done to show military authorities throughout the world that it was only a matter of time before wireless would rank as one of the most important, if not indeed the most important, means of communication on the battlefield. The time came all right in 1914, but it is outside the scope of this work to consider the development of electrical communications in war. Let us return, then, to the commercial aspect.

Point-to-point communication was already so well catered for by the telegraph, the submarine cable and the telephone that some markedly spectacular result was essential for the stimulation of public imagination, a necessary preliminary for introducing a new invention to a field of action already occupied.

This spectacular result was supplied by Marconi sending wireless signals for the first time across the Atlantic in 1901, and this event marks the entrance of wireless on to the stage of point-to-point communication. It was a fine entrance, but many years were to elapse before it had any appreciable effect on the actors who were already in possession of the stage. There were various reasons. The old actors were doing very well, whereas the new one suffered from serious technical ailments, and, what was much worse, was soon wrapped up in a choking fog of financial jugglery. The former was inevitable with a new invention, but the latter was not, and to it must chiefly be ascribed the slow initial development of point-to-point communication by wireless signalling. There would be no advantage now in peering through that old financial fog, but it may be of interest, and is certainly much easier, to have a look at the technical ailments.

The principal technical drawback to long-distance wireless telegraphy compared with the submarine cable was its unreliability. Sometimes communication was good, but at other times it was poor or even failed altogether, so that it was impossible to predict what sort of communication would be established at any given time. Such a state of affairs was hopeless for commercial success in competition with a cable which gave regular steady communication throughout the twenty-four hours. Reliability is essential for success in this direction, and this the wireless route could not give.

It was far cheaper to install, but its running costs were greater, and its unreliability put it out of court as a serious competitor with the cable. This drawback did not hold good for short-range working, but there was no room for that. The world was already well supplied with short-distance cables, and all civilised countries had a network of inland telegraphs. Wireless did, indeed, find an opening for inland work in sparsely populated areas, but it had little encouragement there from the commercial point of view.

Another great technical drawback was that wireless messages between two places interfered with wireless messages between other places within range, unless the wave-lengths used were greatly different. The number of wave-lengths available was small, so that the possible number of point-to-point channels was small; far too small to allow of competition with inland telegraphs. This drawback, like the former one, has of course lessened as wireless has developed, but it is still far too serious to allow of any competition with inland telegraph lines in a small country. It is, in fact, so serious that point-to-point working by wireless between places in this country has never been permitted by the Government.

The conditions are rather different in a large country like the United States, and still more different on the continent of Europe where the inland lines run through a number of different countries. In the former case there is some opening for wireless, due to the extent of the large area available, and in the latter case direct communication by wireless between distant places has the additional advantage of cutting out the expense of meeting the transit charges imposed by the various countries through which the landlines pass. There has developed accordingly of late years a considerable number of wireless point-to-point services in America and in Europe, including many services between England and the Continent.

The charges made for communication between this country and the Continent are the same whether the route used is by wireless or by cable and landlines, but the fact of having the two routes available in many cases ensures a better service. The charges for most of the really long-range wireless services, including the Beam Imperial Services, were less than the cable charges, and we have seen in a previous chapter how the success of these Beam services seriously affected the position of the cable companies, and resulted in a combination of cables and wireless for Imperial communications. Now cable rates are being reduced to the same level as wireless rates.

The development of wireless for point-to-point communication was thus confined, from the start, to long-range working, and its main trouble was unreliability. At first, efforts were made to overcome this trouble by increasing the power at the sending end, and the sensitivity of the receiving apparatus at the receiving end. The increase of power involved larger aerials and longer waves; the increase of sensitivity involved better receiving instruments and directional aerials. This, indeed, sums up the first ten years of technical advance in point-to-point communication. Then came the introduction of continuous-wave transmitters and valve-receivers, and for the first time the cable companies saw the red light; dimly it is true, but the glow was there. By 1928, when the Post Office had established the commercial success of Marconi's short-wave Beam System, the glow became a blaze, and the cable companies in this country saw that, unless they swallowed up the wireless, the game was up. The whole matter was considered by the Home Government, the Dominions and India, and, as already described, it was decided to merge the cable and wireless interests of the Empire into a new company which would be subject to a certain amount of Government control. The transfer to the new company took place in September, 1929, and, so far as our Imperial Communications are concerned, wireless and submarine cable telegraphy, the old rivals, are now advancing hand in hand.

The traffic work of this new commercial merger is in the hands of the Imperial and International Communications Co., Ltd., the manufacturing work being in the hands of an allied company, Cable and Wireless, Ltd. The combined capital of these companies exceeds £53,000,000. This was the first great merger of cable and wireless interests in the world, but there seems to be a desire in the United States for some similar combination between cables and wireless there, and a strong move to get rid of legal restrictions which at present stand in the way of such a combination is now in progress.

In the case of wireless telephony the circumstances were altogether different as there was no question of competition, for the simple reason that long-range submarine cable telephony was still an unsolved problem, though, as we have already seen, this state of affairs will not last much longer. Wireless telephony, therefore, was not included in the merger company's activities, and remains, as hitherto, in the hands of the Post Office.

But we have got too far ahead, and must return for a moment to glance at the developments which led up to the present arrangements. We have seen that Marconi's inauguration of the transatlantic service was the real beginning of point-to-point wireless telegraphy, and that for several years technical difficulties kept it far behind the cables. By 1912, however, this particular service, along with a few others which had been established subsequently in other parts of the world, was giving a really satisfactory service, though, of course, not up to the cable standard, and the Government decided to embark on a scheme for linking up the Empire by a chain of high-power stations.

This scheme unfortunately got mixed up at the outset in the financial jugglery to which we have already referred, and it was not until the following year, after a stormy Parliamentary passage, that an agreement was come to between the Post Office and the Marconi Company for putting the work in hand.

Stations were to be erected by the Company for the Government in England, Egypt, Kenya, India, Singapore, Hong Kong and Australia, but the outbreak of war in 1914 held up the scheme.

The erection of the English and Egyptian stations had been commenced, temporary apparatus was installed, and a certain amount of use was made of them during the War; but otherwise the scheme was stillborn, and no further attempt to erect high-power stations was made by this country during the War. We were well supplied with cables and relied on these for world-wide communications. Our allies, however, were differently placed in that respect, and a number of high-power wireless stations were erected during the War in the United States, France and Italy. This was the period when Arcs and Alternators came into use for transmission, and the Valve for reception; it was the time of the first red glow for the cable companies, but they were far too busy to take much interest in it just then.

As soon as the War was over, however, the glow became apparent, and the cable companies went all out to increase their carrying capacity. In a previous chapter we have seen how they succeeded in doing so by the invention of loaded cables, new magnifiers and regenerators, improvements which more than counterbalanced the technical strides which had been made by wireless in the War, and which placed the cables again in an apparently impregnable position so far as competition with wireless was concerned. But point-to-point wireless got busy too—in fact, very busy indeed; and we shall next trace its rapid development from the War to the present day.

CHAPTER XVIII

POINT-TO-POINT WIRELESS (*continued*)

WE have already described in broad outline the development of point-to-point wireless telegraphy from the first transatlantic circuit in 1902 up to the end of the War. As soon as the War was over, the Government again turned its attention to the development of the wireless communications of the Empire, and at the close of 1919 the whole subject was referred to a Government committee under the chairmanship of the late Lord Milner.

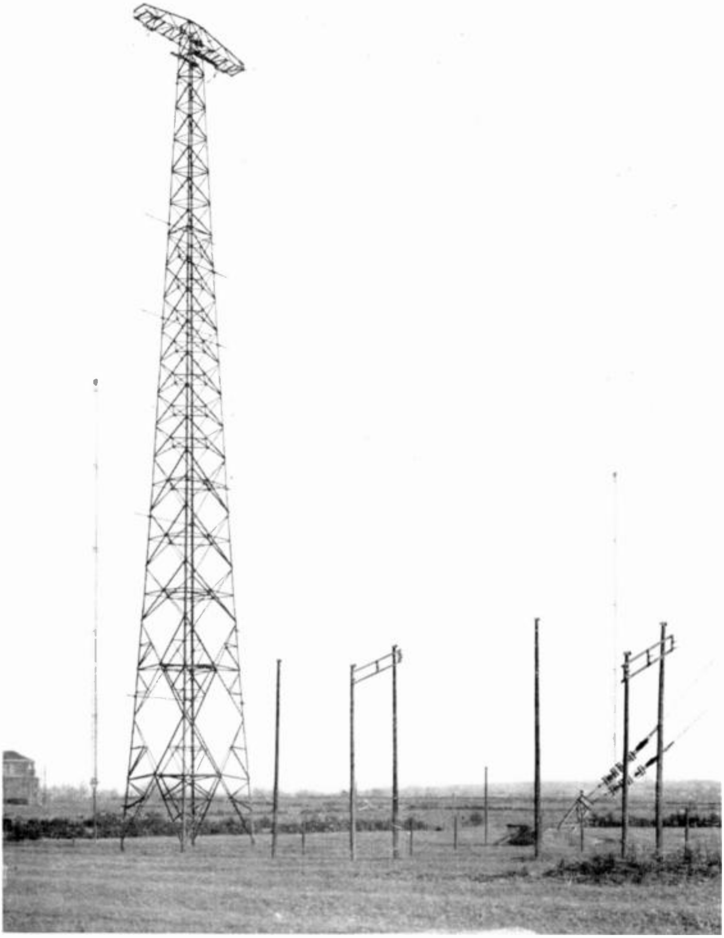
This committee produced a new scheme for imperial high-power stations of the latest design, some with valve and some with arc transmitters, but the idea of a chain remained, an idea which was not welcomed by the Dominions or India, who wished for direct communication with this country and with each other, as opposed to communication through intermediate stations.

With the knowledge then available—fortunately, as it turned out—this direct communication was impracticable, and the scheme was being delayed, when in the spring of 1924 Marconi announced the extraordinary results which he had obtained by the transmission of short waves over long distances in the form of a beam. Within a few months the Post Office had signed a contract with the Marconi Company for the erection of short-wave beam stations in this country for communication with similar stations in Canada, Australia, South Africa and India. At the same time it was decided that the Post Office should complete the erection of the English station at Rugby, under the old scheme. This station was to be by far the most powerful valve station in the world, and presented a host of problems which had never before been tackled.

It was an inspiring time for the wireless engineers of this country. They were erecting two new systems for world-wide telegraphic communication, one on short waves for communication with definite points, the other on long waves for broadcasting all over the world; and they were engaged on a third new system, in co-operation with the United States, for opening up transatlantic telephony for the first time in history. Ever since the War it had been said on all sides that England was being left behind in the development of wireless signalling. This great effort was to be the answer, and the rest of the wireless world, just a little nervous, sat back in its chair and waited.

It had not long to wait. In January, 1926, Rugby started broadcasting messages by wireless telegraphy to stations and ships all over the world. In January, 1927, the Rugby wireless telephone transmitter got busy, and for the first time a commercial long-distance wireless telephone service was established, viz., the transatlantic service with the U.S.A. In November, 1926, a commercial high-speed wireless telegraph service on the Beam system was established with Canada, to be followed, in 1927, by similar services with Australia, South Africa and India.

Those two years, 1926 and 1927, changed the whole course of wireless development. England, far from being behind, had thrown into the melting pot all the



Pl. XX. *h* 135.

At the Rugby Wireless Station.

A 180-ft. mast, with two of the 820-ft. masts in background.

long-established ideas about world-wide electrical communication. The rest of the world had looked on and waited to see what would happen, and what did happen was well worth waiting for; a new era had opened, and, honour to whom honour is due, this new era was the direct result of years of strenuous work on the part of our Post Office engineers, the engineers of the British Marconi Company, the engineers of the American Telephone and Telegraph Company and of the Western Electric Company, and last, but not least, the genius and driving force of the greatest of all wireless pioneers, the Marchese Marconi.

Short waves had been used experimentally for several years before Marconi carried out his successful Beam experiments, but they had not been developed for commercial working. We have already seen how prominent a place was taken in the pioneering work on short waves by amateurs in this country and in the United States. The climax of these experiments was reached in October, 1924, when Mr. Goyder, then a boy at Mill Hill School, established communication with Mr. Bell in New Zealand, but much of this early amateur work has been rather overshadowed by Marconi's famous experiments which led up to the brilliant success of his Beam system as a commercial proposition.

This success may be judged by the fact that the amount of traffic being handled by the Post Office on this system with Canada, Australia, South Africa and India was about 900,000 words a week when the circuits were transferred to the Merger Company in September, 1929. The speeds obtained on these circuits vary from about 100 to 200 words a minute, duplex, according to conditions, but in regularity of working they are not yet up to the level of cables. The circuits, which were operated from the General Post Office, are now, under the merger arrangement, operated from Radio House in Wilson Street, London, and will be transferred later on to the headquarters of the new company on the Embankment. The transmitting stations for Canada and South Africa are at Bodmin, and for Australia and India at Tetney, the receiving stations being at Bridgwater and Skegness respectively.

The wave-lengths now used for each service are below 40 metres and are the result of practical trial. There is still much to be learned about the conditions of propagation of short waves, as these alter according to whether the great circle path which passes through the two stations is in daylight or darkness, or a combination of the two. Generally speaking, short waves fall off in strength up to a range of about 100 miles, but waves below about 60 metres become stronger as the distance increases, and in daylight the shorter the wave the greater the recovery in strength. This is generally explained by the fact that, up to about 100 miles, propagation depends mostly on direct rays which are emitted from the aerial at low angles and whose energy is rapidly absorbed. At greater distances it is assumed that the increased energy is obtained from radiation which leaves the aerial at higher angles, travels along a conducting layer some 50 miles above the earth with little absorption, and is later on bent down to the earth again.

The power used at each transmitter is about 25 kw., and the methods of transmission and reception of signals are those described in a previous chapter which dealt with the latest developments of machine telegraphy ; in fact, the operation of all modern point-to-point wireless circuits is now on the same lines as modern line telegraph working where the Morse code is used.

The great advantage of being able to use short waves for long-range communication is that far less power is required, which means not only a great saving in running costs but a great saving in capital expenditure. For instance, a world-wide long-wave station like Rugby costs somewhere about £500,000 to erect, about ten times as much as a short-wave station, and as the power used is in even greater proportion, the running expenses are much greater. Then, again, the speed of signalling of a short-wave station is greater than it is possible to obtain from a long-wave station, another advantage of the first importance, though, as a slight set-off to this, the regularity of communication is greater with the long-wave station unless strong atmospheric disturbances are present.

The only long-wave stations in this country are the Post Office station at Rugby and the Communications Company's station at Carnarvon, but, in addition to short-wave stations, some medium-power transmitters are in use for continental communication, some of which is carried out by the Post Office and some by the Communications Company. The Post Office transmitters are at Rugby and Leafield, the Company's at Ongar, the former being operated from the General Post Office in London, the latter from the Company's offices at Radio House in Wilson Street. The Post Office receiving stations for this work are concentrated at St. Albans, the Company's at Brentwood.

The medium-power transmitters are only suitable for continental services, but the short-wave transmitters are used as well for transatlantic and other long ranges. The most interesting and important short-wave services, however, are the imperial services on the

Beam System, as it was the great success of these services which forced the merging of the cable and wireless interests.

The terms short and long waves are very vague, and at an international conference, which was held at The Hague in September, 1929, it was decided to classify waves as follows: Below 100 Kilocycles per second (over 3000 metres) as Long Waves, 1500 k.c./s (200 metres) to 100 k.c./s (3000 metres) as Medium Waves, 6000 k.c./s (50 metres) to 1500 k.c./s (200 metres) as Intermediate Waves, and 30,000 k.c./s (10 metres) to 6000 k.c./s (50 metres) as Short Waves, above 30,000 k.c./s (below 10 metres) as Very Short Waves.

The range obtained with long waves varies acccording to the power used. What may be called continental range may be obtained with any long waves, but for world-wide range it is necessary to use very long waves of nearly 20,000 metres. Medium and intermediate waves are of use only up to continental ranges, but short waves again have world-wide range. Very short waves are still in the experimental stage.

As regards the mutual interference caused by world-wide short-wave services, the Hague conference considered that practice has shown that a separation of waves by 0.1% frequency was necessary if interference was to be avoided. This limits the number of such stations to about as many as are at present working or are projected, so that one may well wonder what the future has in store for world-wide communication. Only a few years ago we were told that very soon there would be no more channels available for world-wide communication on long waves, but that the introduction of short waves would clear up the situation. But here we are again at the old question of the troubles caused by interference. It is as old as wireless itself, and the answer no doubt will be supplied, as it always has been in the past, by the most enthusiastic body of workers in the world, the wireless engineers, and their colleagues, the amateur experimenters.

CHAPTER XIX

AT THE RUGBY WIRELESS STATION

THE necessity for a wireless station with a world-wide range having become apparent to the Government several years ago, steps were taken to put the project into being. A Wireless Telegraphy Commission was appointed, as already noted, with the late Lord Milner as chairman, and this body studied the problem in association with the Post Office engineers. As a result of their deliberations the Rugby Wireless Station was opened in 1926.

It was necessary first to find a suitably large area. This was secured at Hillmorton, some four miles to the south-east of Rugby. Here the ground is level with open country around, while an adequate water supply is provided by a small stream in the vicinity. It was an admirable position for the proposed station, and full advantage has been taken of the natural facilities afforded.

Incidentally, the Rugby station includes the site of the once famous Handley Cross Farm, the scene of the exploits of the genial Mr. Jorrocks, whom readers of Surtees' novels will remember. This portion of Warwickshire has long been a noted hunting country. When the property was purchased the old farm was demolished, and where it formerly stood is now one of the new buildings of the station. In all, the area covered is 900 acres, its proximity to the railway and the

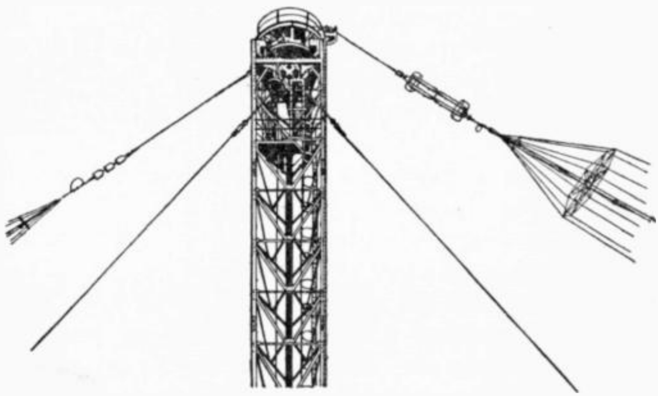
Oxford Canal giving it an added advantage in regard to transport. As the traveller on the L.M.S. line, going northward, approaches Rugby, he is given a glimpse through the carriage windows of the tall steel masts with their aerials which are the most conspicuous feature of the station.

It is not the province of this chapter to enter fully into technical details in describing the equipment and working of the Rugby Wireless Station. Some such matter must be dealt with to understand its activities, but so far as is possible a general survey will suffice.

One of the first questions to be considered by the Commission was that of power supply. This problem was solved by the securing of the main power from the Leicestershire and Warwickshire Electric Power Company whose stations are at Warwick and Hinckley. The current thus obtained is passed through transformers and conducted to the motor-generator sets in the machine-room. The three main machines here are each capable of supplying a voltage of 7,000 volts. No self-generating machinery, therefore, has been necessary for the station.

Before dealing with the actual work performed at Rugby, with the long-distance telephones to the U.S.A., Australia and elsewhere, we may first consider the equipment. The installation of masts is the most striking feature. These are 47 in number, at the time of writing, but it is planned to erect others. Twelve of the masts are big steel structures, each 820 feet in height, stayed, and of the pivoted type, resting on a concrete foundation. Some idea of their strength and size may be gathered from the following figures: the weight of the steel-work in a single big mast is 170 tons; the weight of the stays is 28 tons, there being five sets of the latter, three per set. With erections of so great a height, wind pressure had to be allowed for, so they were designed to stand against a wind load of 60 lb. per square foot on the projected surface. The horizontal aerials at the top have a pull of 10 tons.

The aerials on the twelve tallest masts radiate in all directions ; those on the 26 smaller ones are directional, and of these latter aerials three or four are directional to the U.S.A., three to Australia, and three to ships which voyage between Southampton and New York.

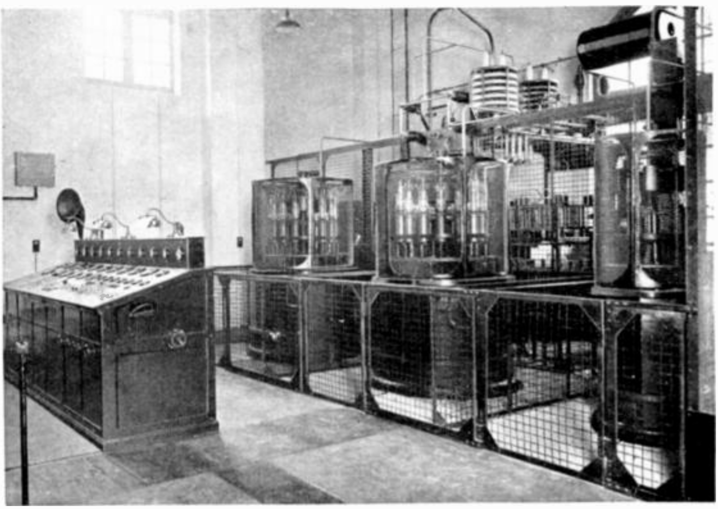


TOP OF ONE OF THE 820-FEET MASTS AT THE RUGBY STATION

The last-named are set in a mean line between the two sea passages that are followed. The shorter masts are of the self-supporting type and range from 120 to 180 feet in height.

At the base of the big masts is the earth system, consisting of 80 miles of copper wire weighing 100 lb. per mile, buried a few inches below the turf. The "earthing" follows the plan of the aerials, reaching out to a distance of several hundreds of feet on either side of the base, and the wires are conducted from the

The Rugby Wireless Station.



Pl. XXI. *K* 142.

Inside the Rugby Station.

Showing long-wave wireless telephone transmitter and control table.

ground near the buildings to lead into the transmitting room.

Much might be said about the elaborate insulation system of the masts and the aerials, but these are more matters for the expert. It may be noted, however, that two separate aerials having different capacities may be employed, or the two may be combined to form a larger aerial.

Next to the power plant, which supplies the life-blood of the Wireless Station, the main point of interest is the Transmitter Room. Here are to be seen the condensers, coils and transformers, with the lead-out to the aerials, the switchboard for tuning-fork units, the landline apparatus, control table, switchboards, motor-generators and air-compressors. Of these the control table calls for special comment.

Fitted with press-buttons to start or stop auxiliary engines, with the air-compressor for keys, and the high-tension direct current switch, with switches for the distilled water-pump, the cooling water-pump and the main filament supply, and with voltmeters and ammeters applied to several uses, it contains also the apparatus which terminates the landline from the Central Telegraph Office in London. There are in addition a loud-speaker and a wireless recorder which check the signals transmitted from the aerial. While the operator sits at work at the table he has ready to his hand an "engine-room telegraph," by means of which, employing push-buttons, he can direct the power-house as to the requirements of electrical power.

Now as to what is actually done at the Rugby Wireless Station in the matter of transmission. It is the world's largest wireless centre, and it never closes down. Day and night it is busy transmitting to the far ends of the earth and to ships all over the world. For this work it employs the following sets: 1 Telegraphy (long wave), 1 Telephony (long wave) and 3 Telephony (short waves) for transatlantic transmission, 1 Telephony (short wave) for Atlantic liners, 1 Telephony (short wave) for Australia, 1 similar set for expansion, and 1 Telegraphy (medium wave).

In connection with ship communication we may note some interesting particulars. As explained elsewhere, every sea-going British ship of 1,600 tons gross tonnage or upwards is required to be fitted with a wireless installation. To all such vessels, large or small, which are fitted with the special receiving apparatus to enable them to take messages from Rugby, the station broadcasts Government news messages free of charge three times a day. Many large ships, too, are now fitted with short-wave installations, enabling them to send as well as receive messages over world-wide ranges.

From Rugby, wireless telegraphic messages are dispatched on medium waves to Hungary, Italy, Czecho-Slovakia and Poland, among European countries, the replies from these being received at the Post Office receiving station near St. Albans, Herts., and relayed over landlines to the G.P.O. in London.

It is in wireless telephony more than in wireless telegraphy that the greatest strides have of late been made. Rugby amazes the uninitiated with its evidence of the wizardry of modern science. In one of its buildings are three telephone sets—one for the Australian service, one to the U.S.A., and a third for communication with certain ships at sea. What has been done in regard to wireless telephone connection with ships is truly remarkable. Not much more than a year ago only some fishing craft, including whalers, made use of telephony, mainly because its expense in comparison with that of telegraphy did not commend it to ships in general. It was the short-wave working (still partly in its experimental stage) that changed this state of things. On the 8th of December, 1929, wireless telephone communication was established between the liner *Leviathan* and telephone subscribers in New York during her voyage to this country. Messages were transmitted over a distance of 2,600 miles.

It was a great step forward, and the British Post Office quickly responded to this transatlantic challenge. In February, 1930, a service was opened from this side with the *Majestic*, which sailed from Southampton for New York with a telephone installation, and it was announced that similar facilities would be extended, if desired, to other ships on the same route. At the present time four of the great liners employed on the Western Ocean—the *Leviathan*, *Majestic*, *Olympic* and *Homeric*—are equipped with the necessary transmitting apparatus; in time many other vessels may be expected to follow suit. The utility of the wireless telephone, to the business man in particular, is apparent, and the growth of this quick-service system on the Atlantic will be, it is hoped, rapid when economic conditions improve.

With the U.S.A. and ships, wireless telephonic communication from, or rather, through, Rugby is a 24-hour continuous service; to Australia it is less frequent at present. To the U.S.A., be it said, there are at Rugby one long-wave-length and three short-wave-length telephone channels. Commencing operations in January, 1927, this transatlantic wireless telephone service was (and still is) worked on a wave of 5,000 metres. A little more than a year later a second channel was opened on short waves, to be followed by two more, and ere long another long-wave channel is to be operated. The 5,000 mètres wave-length receiving apparatus is at Cupar, Scotland, and the new installation of a like character will probably be installed there also as the reception conditions for long waves are better there than in the South. It is at Baldock, in Hertfordshire, however, that long-distance messages from America, Australia and ocean liners are received on short waves by wireless telephony, the extension being completed to the listener by landlines.

As an official at the Rugby Wireless Station recently summed it up, this telephone service comprises "Romance and Finance." That is to say, what is mostly transmitted by 'phone consists of private messages and Stock Exchange prices and reports. As one enters the station a loud-speaker may be in operation, the high-pitched tone indicating that a woman subscriber is utilising the service, the lower-pitched note of the mere male operator being always distinguishable.

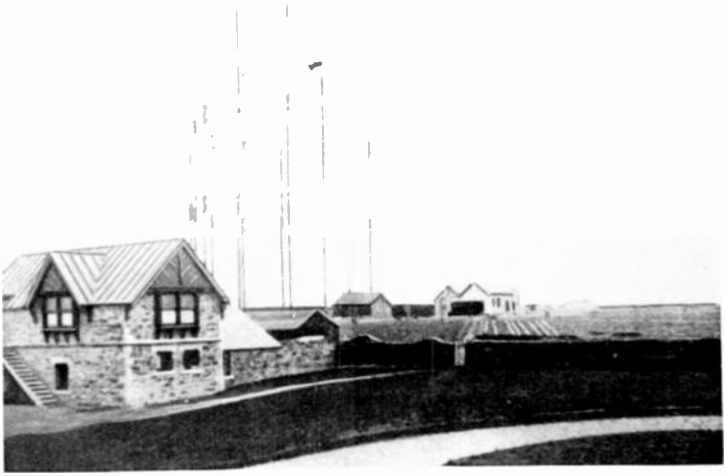
The variety in the nature of messages thus transmitted to America or to Australia is marked. Business matters of urgency, of course, obtain largely; other messages are of a trivial or intimate character. At times even new jazz dance tunes may be sent over, the high cost of transmission, as contrasted with the cost of postal service, not weighing with those to whom time-saving is of importance.

It must be borne in mind that the Rugby Wireless Station itself does not receive messages direct; it is simply a transmitting station. To make this clear, anyone in the town of Rugby, for instance, who wishes to send a telegraphic or telephonic message by wireless to someone in Bristol, or in the U.S.A., or the Argentine, will have to send it through London, which in turn will transmit it through the Rugby station.

That is the essential feature of the station; it is a distributing centre in Great Britain for wireless communication. Government messages, private messages and press matter (Reuter's code, for instance), are sent out from it, together with the periodical time signals transmitted from Greenwich. It is, too, the only station for transmitting long-distance telephonic messages by wireless. Here is an example of the long-distance communication in which Rugby takes part: Melbourne(Australia) talks to Sydney over the land-line; thence Sydney is connected up with London which, in turn, "rings up" New York, and New York passes on the message by landline to the listener at Los Angeles. Estimate the number of thousands of miles thus covered and you will grasp some meaning of the phrase "annihilation of distance."

With so much achieved in a few years it is impossible to place any bounds upon the potentialities of this great wireless station at Rugby. North America, Australia and South America are already linked up telephonically with this country, and thence with Europe. India will be the next part of the Empire to be similarly connected, and South Africa will follow. The Imperial Conference which was held in London recently discussed fully these important developments. Then we shall soon see direct wireless telephonic communication with Egypt and the Far East. What but a few more years may bring forth in regard to complete round-the-world inter-communication by wireless telephony is a question that may be left to the imagination to answer. It is simply a matter of the erection of stations: 1941 will have a far more wonderful story to relate.

In India, which is shortly to come into line, it is proposed to utilise the beam station at Poona for the projected service. South Africa has yet to find a suitable station. Once these installations are completed, however, a really world-wide wireless telephonic link will have been established. And Great Britain, represented by the Rugby Station, will figure as the principal Trunk Exchange. Just as a subscriber at any town in this country must transmit a message for Canada through Rugby, so a subscriber in Australia desirous to speak to someone in Canada must put his call through the same great wireless exchange, "Rugby Radio."



The Marconi Co.'s Wireless Station, Poldhu.

With makeshift aerial in use after storm in December, 1901.

Pl. XXII. *p. 151.*

Receiving Room of I. & I. C. Co.'s Station, Somerton.

For reception of beam messages from U.S.A., S. America, Egypt, Japan and Far East.

CHAPTER XX

WIRELESS TELEPHONY

AS we have already seen, wireless telephony became a commercial possibility as soon as De Forest, in 1907, added a third electrode to Fleming's valve, as this piece of apparatus was then capable of being used as a really efficient transmitter and receiver of continuous wireless waves. But we must go much farther back for the birth of wireless telephony from the experimental point of view. Indeed, no sooner had Bell produced his telephone, than efforts were made to get rid of the connecting wires. The method of induction was tried just as it was tried in telegraphy without wires, and in this country William Preece used induction for telephony, as he had done before for telegraphy; in fact, one of his installations was in use between the Skerries and Cemlyn until quite recently. But these induction arrangements for telephony were only of practical use, like those for telegraphy, for short-distance communication.

Marconi, in 1896, was the first to show that Hertzian waves could be used for telegraphy, and it was clear to all that they could be similarly used for telephony if it were possible to produce them as a continuous stream. R. A. Fessenden, of America, was the first to achieve substantial success in producing continuous waves, and in 1900 he used an alternator for transmitting wireless telephone messages in Maryland over a distance of one mile.

By 1906 he had greatly increased the range of working, and, as already mentioned, he even spanned the Atlantic, wireless conversations between two of his stations in America being overheard at a station which he had erected at Machrinanish, in Scotland. In the same year he demonstrated the practicability of linking up the wireless telephone circuit to landlines, and in the following year he showed the possibility of talking and listening by wireless in the same way as by line telephony, that is, without having to switch over from the sending to the receiving instruments.

Many others were, of course, working along similar lines, notably Lee de Forest in America, Valdemar Poulsen in Denmark, and Giuseppe Vanni, in Italy; but Fessenden was the most successful of the early pioneers in the practical application of wireless telephony.

By 1908 Fessenden was working a practical wireless telephone circuit, with alternator transmission, between Brant Rock and New York, a distance of 400 miles; De Forest had fitted the United States Navy with telephone sets, using arc transmission, and had obtained good communication between ships up to 50 miles; Poulsen was demonstrating telephony, with arc transmission, over distances of 300 miles; and the British, French, Italian and Japanese navies were trying out various systems.

All these early efforts were made with alternator or arc transmission, and magnetic or electrolytic reception, and it was not until the use of the three-electrode valve, first as a receiver and later as a transmitter, became established that wireless telephony began to emerge from the experimental stage.

The first outstanding success was obtained by Vanni, who spoke between Rome and Tripoli, a distance of 600 miles, in 1912; but long-range telephone tests became a dead letter in Europe as soon as war broke out in 1914, and all available experience was directed towards the development of small sets, especially in connection with aircraft. This was due to the fact that the use of wireless telegraphy in aeroplanes entailed the pilot or observer being a trained telegraphist and acting as such in addition to his other duties. Pilots and observers had plenty of other work to do, and the advantage of having a simple telephone set which could be used with little technical knowledge was apparent.

It was in the summer of 1915 that wireless speech from an aeroplane was received for the first time in this country, and there is little doubt but that our Air Force was the leading pioneer in this method of communication with aircraft. One of the first successful demonstrations of wireless telephone working with aircraft in France was given to the late Lord Kitchener at St. Omer. The messages unfortunately were heard as far away as Lowestoft, and further experiments were prohibited for quite a long time, as it was feared that the Germans might obtain some valuable information by reading our messages. By the end of the War it was normal practice for aeroplanes to communicate by wireless telephony with ground stations up to fifty miles, and with each other up to five miles.

During the early stages of the War more time could be devoted in the United States than in Europe to the development of long-range working, and by 1915 the American Telephone and Telegraph Company decided to attempt communication across the Atlantic.

With this end in view they used a large number of small valves in parallel for transmitting from the naval station at Arlington, and succeeded in transmitting speech to the Eiffel Tower station in Paris on the 23rd of October, 1915. This experiment was the starting point of commercial wireless telephony over great distances; that is to say, for the first time the results obtained were such as to show that commercial long-range working might become a practical proposition.

The War continued to delay any spectacular advance in long-distance communication, but in 1923 the Company again made tests across the Atlantic, this time to England, with such marked success that the Postmaster-General decided to co-operate with the Company and with the International Western Electric Company in developing a transatlantic wireless telephone circuit.

The greatest troubles at the outset arose from fading and atmospherics, and for three years daily observations and tests were carried on, both in this country and in America. At last, on the 7th of February, 1926, two-way conversation was held for the first time between England and the United States of America.

This was the greatest advance that had been made in telephonic communication since Bell, on the 10th of March, 1876, made his famous first speech by line telephony in Boston from one room to another, "Mr. Watson, come here; I want you." Bell's somewhat abrupt speech was equalled by England's epoch-making opening remark across the Atlantic, "Hullo, New York; who is that speaking?" but was surpassed by America's laconic reply, "Bailey."

Exactly eleven months later, on the 7th of January, 1927, the transatlantic wireless telephone service was opened to the public. Mr. W. Gifford, President of the American Telephone and Telegraph Company, opened the service by speaking from New York, and Sir Evelyn Murray, the Secretary of the Post Office, replied from London. Both speeches were more expansive, but less technically illuminating, than those of eleven months before.

The telephone channel from England to America was by underground cable to the Rugby wireless station, thence by wireless to Hulton, Maine, a distance of 3000 miles, and from there by open and underground lines to New York. The reverse channel was from New York by underground lines to Rocky Point wireless station, thence by wireless to Wroughton, in Wiltshire, and on to London by underground lines. Later a receiving station was erected at Cupar, in Fifeshire, and another has since been erected at Baldock, in Hertfordshire. The transmitter at Rugby consisted of a 200 kw. valve set, with an aerial supported on masts 820 feet high, and the wave used was about 5000 metres.

The service developed so rapidly that at the end of the first year an additional channel, using short waves, was opened, and two more, also using short waves, followed. The service, as before mentioned, is available throughout the whole of the day and night.

The minimum charge at first was £15 for a three minutes' conversation, but this has since been reduced to £6, and it is now possible for nearly all countries in Europe to hold telephone conversations via the Rugby transatlantic circuit with any part of the United States and the chief towns in Canada, Mexico and Cuba ; in fact, it was calculated some months ago that this service was available to more than 200 million subscribers. It deals with about 700 calls a month.

The Rugby-U.S.A. service was the first long-distance commercial wireless telephone service in the world, but several others are now in operation, notably those between Germany, France, Spain and S. America, between Holland and Java, and between England and Australia, Canada, S. America, etc. Intercommunication, indeed, is already possible between 90% of the world's telephone subscribers. The service is not always good and the charges are often high. These are matters for the future.

It will be noticed that we have confined ourselves solely to the growth of long-range commercial services, but this does not mean that all advance was due to professional workers; far from it. As soon as the War was over the amateurs, as we have already seen, got busy on short waves, and they did not confine their energy to telegraphy where they made such astounding advances. They were soon on the trail of telephony; a long time before the Rugby service opened, amateurs were talking to one another from one side of the world to the other, and their experiences were of great value to the professional workers who were developing commercial services. But we must not lose sight of the fact that to speak over long distances at odd times under certain conditions is a very different proposition from establishing commercial communication; in fact, we have seen that it was twenty years from the time when Fessenden's voice in America was heard in Scotland, before a commercial service was in operation between the two countries.

CHAPTER XXI

WIRELESS TELEPHONY (*continued*)

WE have outlined the development of wireless telephony from its birth to its present proud position in the commercial field of long-range communications, but the outline was far from complete, as must have been obvious to all who have been interested in broadcast programmes during the last eight years.

Even eight years is not nearly far enough back to search for the birth of broadcasting. We must treble the eight, and get back as far as 1907. In that year some tests of broadcasting by wireless telephony were carried out in our Navy, and the first song then broadcast, possibly the first song ever broadcast, was "God Save the King." But we cannot by any means take all the credit for the birth, as our friends across the Atlantic were broadcasting songs and music in the United States Fleet when they made their world tour in 1907-8.

In those early days, arc transmission was the only suitable arrangement, or it would be more accurate to say, the least unsuitable; and in America, De Forest, as usual, was well to the fore. In the year 1909 he installed a microphone in the Metropolitan Opera House, and broadcast the finest voice that has ever been transmitted through the ether, the voice of Caruso.

With such a start as that, is there any wonder, one may ask, that broadcasting took the world by storm? But there was no use trying to storm from an arc, and nothing was heard of broadcasting until the possibilities arising from De Forest's addition of a third electrode to Fleming's valve were more fully understood than they were in 1909. It was, in fact, another ten years before sufficient data had been collected for broadcasting to have any chance of being reckoned as a possible competitor with other forms of entertainment.

Successful experimental broadcasting took place in 1907, but it was not until 1920 that a start was made with broadcasting as an entertainment for the public. It looks as if the growth of television may not be so slow after all when compared with its elder brother who is always held up as a perfect marvel of rapid development.

So many individuals of so many countries claim to have been the first to introduce broadcasting programmes that it is impossible to give a generally accepted name, but one which is accepted by some, though unknown to most, is Steringa Idzerda, of The Hague. Idzerda gave a public demonstration in 1919 at the Third Dutch Trade Fair in Utrecht, certainly one of the first successful public demonstrations of broadcasting as we know it to-day.

In November, 1920, the Westinghouse Electric and Manufacturing Company at Pittsburgh obtained a Government licence to broadcast information and music. This is generally taken as the beginning of broadcasting, though, as a matter of fact, the Dutch concerts had become a weekly feature earlier in the same year, and a time-table of them appeared in a British journal in June. There is little doubt but that the Dutch have a fair claim to the kick-off, though the American forwards at once dominated the game. About the same time there were our own famous broadcasts from the Marconi Company's station at Writtle, inseparable from the name of Captain P. P. Eckersley, and in the spring of 1922 the company were giving regular broadcasting programmes from Marconi House in the Strand.

In the United States broadcasting was let loose all over the country, and the more cautious attitude of the Post Office here came in for a lot of adverse criticism, not unprecedented, from those who were not fully informed of the circumstances. But the conditions in the United States were totally different from those in this small thickly-populated country, and it was not really sensible to consider that the best lines of development there would be necessarily the best here. Progress was far more restricted over here than in America, but the net result was that both countries soon obtained what best met their needs, while retaining enough elasticity to allow for change, not only in needs but in technical development.

In the summer of 1922 some of the leading British manufacturers of wireless apparatus approached the Post Office for permission to commence a service in this country, and the result was the formation of the British Broadcasting Company. The agreement was finally executed on January 18th, 1923, but broadcasting services had actually commenced on provisional permission from the Postmaster-General in November, 1922. At first there were two forms of receiving licence, the broadcast and the constructor's, but on January 1st, 1925, the uniform 10s. licence was introduced for the listener, a word first suggested by Sir Henry Norman as a compromise between what some called a listener-in, and others a listener-out. The company's licence expired at the end of 1926, and the British Broadcasting Corporation, incorporated by Royal Charter and operating under licence from the Postmaster-General, took over the business on January 1st, 1927.

When the company started broadcasting in November, 1922, there were about 20,000 licences, and now there are about 3,500,000. During the last four years there have been about 3,500 prosecutions against persons receiving without a licence, so that we are not yet in the happy position of some other countries where there are no "pirates"—and no fees. But, after all, we are spared advertising by broadcasting, and that is well worth "pirates" and fees.

In considering the phenomenal growth of broadcasting during the last eight years it is interesting to note that there are already over 20,000,000 sets in use, of which nearly one-half are in the United States. The number of broadcast receiving sets has thus reached in eight years a total of about half that attained by the ordinary telephone which started on its career over fifty years ago. In this country we have 3½ million, and the number is still increasing.

It is unnecessary to say anything here of the technical development of broadcasting in these last eight years, as the lines of advance are well known to most of the readers of this book, so we shall pass on now to another important development of wireless telephony.

Ships' telephony is a development which bids fair to loom large in the immediate future. Here, as in the wireless telegraphic communications of ships, there is a free field for development, as there is no other method by which conversations can be held between ships, or between ships and the shore. Indeed, the need is so obvious, and the field of action so apparently free, that we must first explain why this development has lagged so far behind that of wireless telegraphy.

The main reason lies in the phenomenal success of wireless telegraphy for ships' communications. We have seen that this was the first application of wireless telegraphy for commercial purposes, and we have seen how rapidly it was developed for these purposes, as well as in connection with the safety of life at sea. So rapid and successful were these advances that telegraphy was established in an extraordinarily strong position before the invention of the thermionic valve made telephony a practical proposition.

Technically, telegraphy had several important advantages. It was in a high state of development, it was cheaper to install, was more economical of power, and used a universal code which to a great extent disposed of the language difficulty inherent in telephony. Many people were obsessed with these advantages of telegraphy, and even thought that telephony would never find a strong commercial footing for ships' communications. It has not done so yet, but there is really no doubt now, and there never should have been any doubt, that the overwhelming advantage of the spoken word for communication must eventually break its way through all difficulties.

Experiments with wireless telephony for ships' communications commenced immediately after the War, and in this country the Marconi Company were soon in the field. In the summer of 1920 they arranged for conversations with the shore to be held by press delegates in s.s. *Victorian* when proceeding from

England to Canada, and conversations were held at distances as great as 1,000 miles. In August, 1923, the company fitted a cross-channel boat, the *Lorina*, belonging to the Southern Railway Company, and, in co-operation with the Post Office, conversations were held between passengers on board and telephone subscribers in England. This was probably the first time that conversations took place between passengers in a ship and telephone subscribers on shore. The system was then improved so that ordinary duplex telephone working could be maintained, and another steamer, the *Princess Ena* was fitted. There proved, however, to be little demand for telephone facilities at that time, and the whole scheme was abandoned.

Later, the company equipped a number of whalers and lightships, etc., with telephony, and these installations have proved of great value, but it was only within the last year or so, when short-wave working had become better understood, that ship and shore telephony has showed signs of seriously entering the commercial arena.

On December 8th, 1929, the *Leviathan*, when one day out from New York on her way to Southampton, opened a commercial telephone service on short waves with the United States, and Sir Thomas Lipton in that same liner was the first to use the service by 'phoning through to Mr. Rankin in Atlantic City to express his (and our) hopes of bringing home the yacht race cup when he visited the States later for that contest. Satisfactory working was maintained up to a range of 2,600 miles.

The Post Office here opened a service with the *Majestic* on February 14th, 1930 and has since arranged that a service is available to and from any ship on the North Atlantic route which is fitted with suitable apparatus. The minimum charge is £4 10*s*. for three minutes' conversation with £1 10*s*. for each additional minute or fraction thereof. In place of the normal charge a report charge of 10*s*. is payable when for any reason beyond the control of the Post Office the person asked for cannot be found.

The Post Office, indeed, has been fully alive to the possibilities of telephone services for a long time, and its station at the Humber has been fitted with wireless telephony, in addition to telegraphy, for some years, but very little use has been made of it by the shipping community. Germany and some other countries have also recently fitted a number of ships and stations; in fact, it is now at last generally recognised that telephony, in spite of its inherent disadvantages for ship-and-shore work, has made a real start, and is settling down on ordinary commercial lines.

Wireless telephony is used extensively for the communications of aircraft, largely due to the necessity of economising personnel. Telephony can be carried out by someone who is doing something else at the same time, which is not the case with telegraphy, and it has, too, the advantage of not requiring the knowledge of a trained telegraphist. It is also a more direct and rapid means of communication, an obvious advantage of first-rate importance for aircraft. For all these reasons, telephony is used exclusively in small aircraft, but telegraphy finds a place in large craft as, for the same power, it can communicate over much greater distances. All aircraft belonging to this country, and to the other principal countries of the world, must be fitted with wireless apparatus if they are capable of carrying ten or more persons. On the

European airways, telephony is used; and on the Empire air routes, telegraphy, with the alternative of telephony.

Wireless telephony has recently come into use for communication with railway trains, not only for the reception of broadcast programmes, but for conversations with ordinary telephone subscribers. The L.N.E. Railway has recently fitted up some of their trains for the reception of broadcast programmes. In North America and on the Continent such an arrangement is not uncommon, and on some long-distance runs it is possible to get through to ordinary telephone subscribers.

It is of interest to note that in 1930 the Government announced its policy with regard to the development of long-range wireless telephone services. As already mentioned, the late Government transferred the Beam wireless telegraph services, which work overseas, to the Imperial and International Communications Company, and the present Government has now decided that the telephone services will be worked by the Post Office from its transmitting station at Rugby in conjunction with its receiving station at Baldock.

CHAPTER XXII

PICTURES OVER THE WIRE

WE have traced the development of electrical communication by means of symbols and of speech, and we shall now take a glance at the electrical transmission of pictures, which led up to electrical communication by sight, that is, television.

In communication, speed and accuracy are the two great essentials, and television will be incomparably more speedy and accurate than telegraphy or telephony. It will thus, when fully developed, be by far the greatest advance of all in the field of electrical communication.

Television provides for instant communication by sight compared with the considerable time taken in communicating by telegraphy or telephony. Picture telegraphy also holds great possibilities in this direction of hastening the speed. In 1930, for instance, the front page of a Californian newspaper was sent by wireless by picture telegraphy 2,500 miles across the United States. It was reprinted and read on the Atlantic seaboard within three hours of its leaving the presses in San Francisco. In this experiment the paper used was only 8 inches wide, and to complete the page three strips had to be recorded and pasted together, so that with improved apparatus it is obvious that the time could be considerably shortened.

Experiments in the electrical transmission of pictures and writing began in the early days of telegraphy. Bain, of England, invented a chemical recorder in 1842. Improved forms soon appeared, and in 1862 Caselli, of France, opened a service between Paris and Amiens for the transmission of drawings. This service continued in operation for several years. At the sending end, a cylinder, with a sheet of tinfoil wrapped round it, was revolved, and a needle traced out the drawing spirally with special ink. At the receiving end, a cylinder revolved in synchronism with the transmitting cylinder. The receiving cylinder was wrapped round with chemically prepared paper, and a needle traced out the drawing. The whole thing was crude and gave crude results, but the general idea bore a striking family resemblance to the latest types of picture telegraphy.

The possibility of commercial picture telegraphy first became apparent in 1873, when it was found that selenium was sensitive to light rays, and at that time Graham Bell experimented with picture transmission when he was grappling with the problem of sound transmission as described in an earlier chapter. A host of experimenters were soon at work, all using very similar arrangements, with the notable exception of Campbell Swinton in England, and Rosing in Russia. These two struck out a new line by employing a cathode ray system of transmission in 1907, an idea which it is claimed by some may still bear fruit in the development of television.

This year, 1907, may indeed be taken as the year when picture telegraphy became a practical proposition, and the first successful system employed was due to Korn of Germany. It would be wearisome to trace out the developments from that time to the present day. They consisted of details, not of principles, and it will be of more interest to summarise the principles at the root of all systems of picture telegraphy than to attempt a summary of the details of development.

The first essential is some means of translating the light and shade of a picture into corresponding variations of electric current; the second essential is a medium between the sending and receiving station capable of transmitting this varying current without distortion; and the third essential is some means of re-translating variations of electric current into light and shade so as to make up, at the receiving end, a replica of the picture at the sending end.

A picture may be divided up into a great number of parts so that each part is of nearly uniform brightness; then the brightness, so to speak, of each part can be transmitted in the form of an electric current, the strength of which depends on the degree of brightness. The greater the number of parts into which the picture is divided, the better will be the reproduction at the receiving end, but the greater will be the time occupied in the transmission.

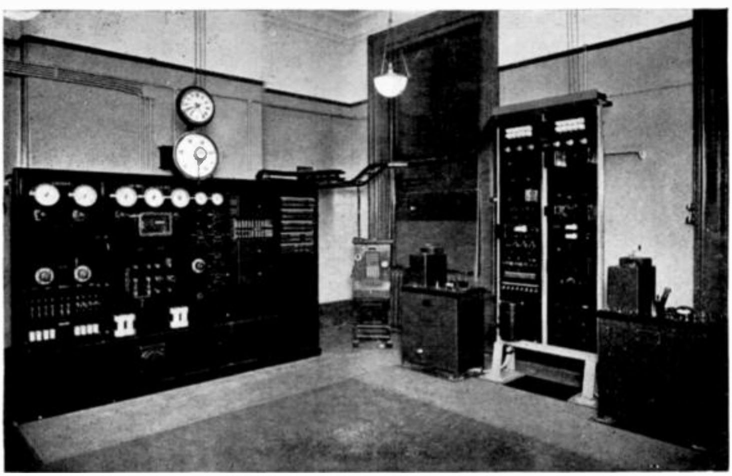
At the sending end, the picture is wound round a cylinder which, while rotating uniformly, moves along slowly in the direction of its axis. A spot of light is made to scan the picture in fine, closely packed parallel lines, and this light, passing through the picture, or in some systems being reflected from it, falls on a photo-electric cell, which is described in the next chapter. The spot of light sets up action in the cell, which translates the variations in the intensity of the light, caused by the relative brightness of the parts of the picture, into electrical variations which are transmitted through the medium, that is, along a wire or through the ether of space, to the receiving end. At the receiving end, the process is reversed, the variations in current producing variations of light, which act on a photographic film wrapped round a cylinder, which rotates in synchronism with the cylinder at the sending end.

Various methods for obtaining this synchronism are employed in the different systems.

The Siemens-Karolus system, which is now in use commercially between this country and the Continent, obtains synchronism by using at each end exactly similar tuning-forks, an arrangement which obviates the necessity of the synchronising signal used in some other systems.

The speed at which pictures can be transmitted in line working depends largely on the type of line, an overhead telephone line, or lightly loaded cable, being the most suitable arrangement. When the ether of space is used as the medium, that is, in the case of wireless transmission, the problem becomes more complicated, due to jamming, fading and atmospherics, but several systems now in operation give satisfactory results; for example, there is the Marconi Company's transatlantic wireless picture service, which has worked successfully for several years. This company is now arranging for a similar service between the beam wireless stations in England and South Africa. Recently arrangements have been made for picture services between some European countries and America through London via the transatlantic wireless circuit. The value of this service for facsimiles of documents, as well as drawings and pictures, is obvious, and it has even been used for the transmission of such unlikely matter as the fingerprints of criminals.

Picture Transmission.
Showing the cylinders round which pictures are wrapped.



Pl. XXIII. *M 167.*

The Picture Transmission Room at the G.P.O., London.

In the United States, picture telegraphy over land-lines is becoming quite popular, and recently a New York firm sent out 300 picture telegrams of the latest feminine fashions all over the country, and, incidentally, received over 200 orders by return.

France was the pioneer of commercial picture telegraphy in Europe, and was followed by Germany and England. Several newspaper services have been in operation for some years in this and other countries, but the *Scotsman* was able to announce in August, 1928, that it was then the only newspaper in the world that owned and operated its own picture telegraph system. Incidentally, the same newspaper was the first in this country to have a private telegraph wire.

The principal systems now in use are the Belin, the Bell, and the Siemens-Karolus. The Belin system is used extensively in France and is employed on a service between Pekin and Mukden in China. The Bell system has a service in America between New York, Boston, Atlanta, Cleveland, Chicago, St. Louis, San Francisco and Los Angeles. The Siemens-Karolus system is used between this country and the Continent, and for a service between Berlin, Frankfort-on-Main, Copenhagen, Vienna and Stockholm.

On January 7th, 1930, the Post Office opened a commercial line service between London and Berlin. This was the first commercial picture telegraph service established between this country and the Continent. Normally a picture handed in at Berlin is delivered to an addressee in London within two hours. The charge is 2½d. per square centimetre, with a minimum of £1 for 96 square centimetres (about 15 square inches). The maximum size is 450 square centimetres (about 70 square inches), for which the charge is

£4 13*s*. 9*d*. Similar services have since been opened with other places in Europe.

As an instance of the progress being made in this direction, we may note that the International Telephone and Telegraph Company gave an interesting demonstration of picture telegraphy at Hendon in March, 1931. Sixty pages of printed matter (1,500 printed words to the page) were telegraphed in an hour, and it was stated that future models were expected to work at a speed equivalent to 180,000 words an hour, which is some six times faster than any other method now in use.

Undoubtedly there is a great future for picture telegraphy as a means of electrical communication, and to those who recognise its possibilities its commercial progress so far has been rather disappointing. At present the apparatus is costly so that it has only been installed at large centres which means that the traffic to and from smaller places has to be sent by post from or to the large centres. This is, of course, a great drawback, but even so the potentialities of the various services available have not yet been recognised by the public. When it is realised generally that long messages can often be sent by picture telegraphy cheaper than by ordinary telegraph the traffic will no doubt increase rapidly. At present this service is used chiefly for news pictures and engineering drawings, schedules and the like.

CHAPTER XXIII

TELEVISION

THE telegraph, the telephone and even the picture telegraph, both by wire and wireless are now well advanced in commercial development. Wonderful as they undoubtedly are, we have already come to look upon them as commonplace, but in the realms of electrical communication there is always something new just on the point of bursting forth on to the commercial stage. The something now is television. Unfortunately, the christening ceremony took place very early, and apparently in a hurry. The words telegraphy and telephony, writing and speaking at a distance respectively, are each derived from two Greek words, but television, seeing at a distance, (*tele*, Greek, " at a distance," and *videre*, Latin, " to see "), is enough to ruffle the hair of a philologist, " Teleopsis " would have been just as easy, and would have let his hair remain in peace, but it was not to be ; someone, who has been wise enough to remain anonymous, christened this latest development of electrical communication, " television," and television it will remain. It might be worse. Look at the " Valve," in wireless telegraphy ; that was fairly bad, but the Americans went one worse and called it a " Tube," and whatever it is, it certainly is not a tube.

But enough of words, it is the thing that matters, and it must be evident to all that for the communication of human intelligence over a distance, sight is quite as important as hearing or writing. The three combined are essential for communication in its fullest sense. Telegraphy and telephony were great steps in advance, but they left a gap. Recently, as we have seen, the gap has been partly filled by picture telegraphy, and ultimately it will be completely filled by television. But we have a long way yet to travel before television fills the whole gap.

Television signifies seeing instantaneously by electrical means what is happening afar off. By television you, my reader, in your home, could have seen me writing this sentence. If I had sent you by telegraphic means, a photograph of myself in the act of writing, that would have been picture telegraphy, a very different thing. The development of these two methods of communication has been, however, along similar lines. The first glimmer of the possibility of television appeared when the properties of selenium were hit upon, quite accidentally, in 1873, by Mr. May, an operator at the transatlantic cable station at Valentia in Ireland. May noticed that his instruments behaved in a peculiar manner when the sun's rays fell on some selenium resistances in the circuit. The electrical resistance varied with the intensity of the light, and this was at once seen to open up a new possibility, viz., the transfer of light into electricity; that is to say, variations in the intensity of light could be made to produce variations in an electric current.

We have seen how this principle was applied to the transmission of pictures by electrical means, but even for that purpose the rate of response in selenium was too slow to allow of satisfactory results. The same difficulty, but to a far greater extent, was experienced when endeavouring to use selenium for television; in fact, it was soon foundto be impossible to expect television results of any practical use when employing anything which had such an appreciable time lag as selenium. Indeed, unless there is no lag at all between the changes of light intensity and the changes of current strength, good television cannot be attained.

It is this necessity of having no time lag between the changes in light and the changes in current that suggested to Campbell Swinton in England and Boris Rosing in Russia, in 1907, that use might be made of the cathode ray, both for the transmission and reception of television. Cathode rays are produced by an electric discharge in a high vacuum. The rays can be diverted from their path by magnetic or electric means, and as they have no weight there is no limit to the speed at which they can be diverted—that is to say, there is no time lag in their movements. So far, the suggestion has produced no satisfactory system of television, though Rosing did, in fact, produce a system which promised well at the time but was not apparently suitable for further development. The general idea, however, is still considered by some to have possibilities, though the discovery of better light-sensitive devices than selenium has turned development into other channels.

Selenium, as we have seen, is unsuitable, but it was found that some other metals, notably rubidium, potassium and sodium were more suitable, and a device called a photo-electric cell was developed. Numerous types of cell have been tried from time to time. The cell consisted essentially of a plate of one of these metals connected to the negative pole of a battery to form the cathode, the anode consisting of a loop of wire close to the cathode, and the whole being arranged in an atmosphere of helium or neon gas. Under the action of light the cathode emits electrons, and for all practical purposes the response is instantaneous. Selenium, though too slow in response, was sensitive enough for television purposes, whereas the difficulty with the photo-electric cell was that, though the response was instantaneous, it lacked sensitivity. The discovery of the wonderful current-amplifying properties of the Valve has to some extent got over this difficulty of insensitiveness. But that this difficulty wants some getting over will be recognised from the fact that the amount of light reflected back from a human face illuminated by a lamp of a thousand candle power at a distance of a yard is less than that of one candle power, and that in television only an infinitesimal fraction of this one candle power reaches the photo-electric cell at any given instant.

There have, therefore, been two outstanding discoveries which have paved the way to television; first, the photo-electric cell by which varying intensities of light can produce instantaneously varying strengths of electric current (and vice versa), and, secondly, the thermionic valve by which the strengths of these currents can be enormously magnified. Since these discoveries were made scientists and what are called amateur workers, all over the world, have been using them in endeavouring to develop practical systems of television. Notable amongst these have been Belin, Holweck and Dauvillier of France, Karolus of Germany, Alexanderson and Jenkins of America, Mihaly of Austria, and last but most successful of all, Baird of Scotland. It is outside the scope of this book to discuss the details of the various arrangments that have been developed by all these and other inventors in the field of television. The general lines of advance have not greatly differed, and it will suffice if we consider the matter from a very general point of view.

At the transmitting end, the object is scanned by a point of light, and the reflected light from the object

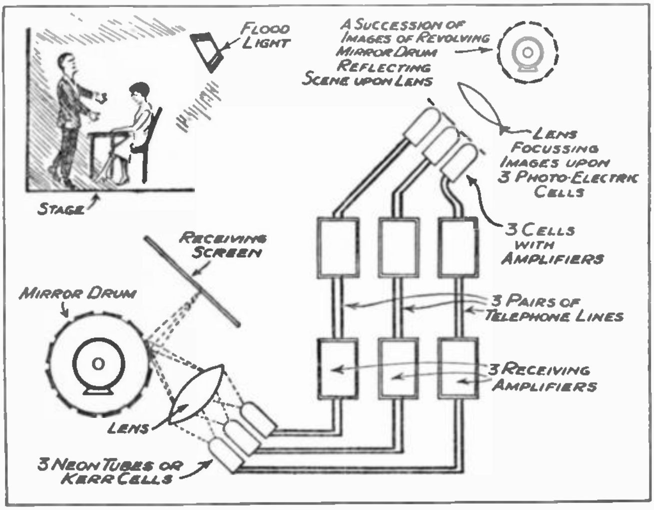


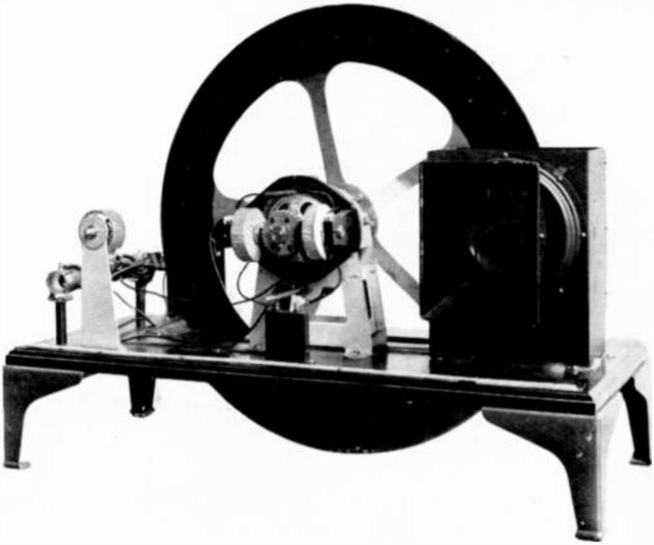
DIAGRAM SHOWING METHOD OF WORKING OF LINE TELEVISION

at any instant is made to affect a photo-electric cell by which a minute current of electricity is produced, the strength of the current at any instant depending on the intensity of the reflected light falling on the cell at that instant. For instance, if the object were all white the current produced all the time would be constant, if it were all black there would be no reflected light, and hence no current. If it consisted of light portions and dark portions, the current would vary in strength at any instant according to the lightness or the darkness of the spot over which the scanning point of light passed at that instant.

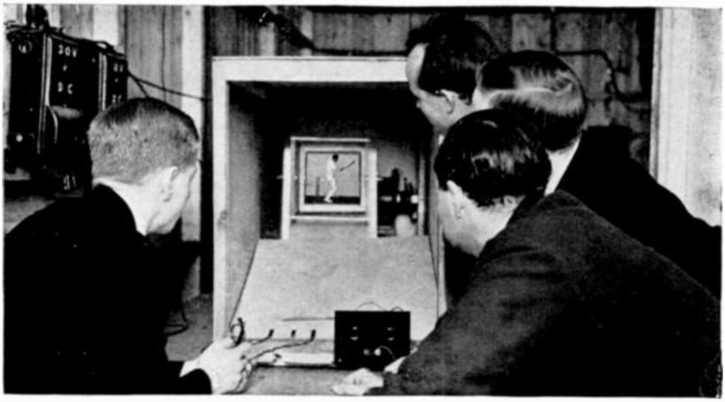
It would seem at first sight that it would be very disagreeable to have a spot of light scanning your face when you wished to have an image of your face sent by television, but, as a matter of fact, when this arrangement is used the spot of light, though necessarily very intense, passes so rapidly over the eye that no discomfort is experienced.

The light is made to scan the object as a spot of light by being made to pass through holes in a revolving disc before reaching the object, the holes being arranged spirally so that the spot of light illuminates successively every part of the object. Every part of the object is therefore illuminated successively so that the object is, as it were, broken up into a series of vertical strips next to one another. This process is repeated each time the disc revolves, the rapidity of the repetitions depending on the speed of revolution of the disc. The light reflected from the object as the spot of light passes over it is made to affect a bank of photo-electric cells so that a varying current of electricity is produced, being at maximum strength when the scanning light spot is on white portions of the object, and at a minimum when it is on black portions. The varying current, which is amplified by valves, is, in effect, an electrical replica of the object, and it can be transmitted by wire or by wireless in just the same way as the varying current produced by the voice is transmitted in line or wireless telephony.

At the receiving end, this varying current is made to affect a source of light, the intensity of the light varying



The Baird Commercial Model "Televisor," without the cover.



Pl. XXIV. *M 174.*

The Baird "Televisor" at Work.

Reception of a picture showing Strudwick, the cricketer, at the wicket.

with the strength of the current. A Neon lamp has been found to be the most suitable source of light for this purpose. A disc, perforated with holes exactly similar to, and revolving synchronously with, the disc at the transmitting end, and a ground-glass screen, are placed between the observer and the Neon tube, so that the observer sees on the screen an image of the object at the transmitting end. The whole image is rendered visible, whether it is still or moving, by being shown at the rate of about sixteen complete images in succession every second, just as pictures are shown at the cinema. This means that the disc at the transmitting end must revolve at such a rate that the spot of light scans the whole object sixteen times in a second, and at the receiving end, the disc must revolve in absolute synchronism with the transmitting disc.

The general principles of television are not difficult to understand, but the practical details involved, though they have been attacked for years, are only now being solved in ways that may, before long, make television a commercial proposition.

For many years experimenters have been able to transmit electrically silhouettes, or what might be called shadowgraphs, of an object, but that is not what is meant by television. True television of an object corresponds to looking at it in a mirror, and what was obtainable until recently corresponds to looking at its shadow, two very different things. We have not yet got to the mirror stage, but we have got to a stage where objects such as the head and shoulders, or even, on a smaller scale, a few people, can be seen in a way somewhat reminiscent of the cinematograph in its infancy, and that, it must be agreed, is a very great advance on shadowgraphs.

The first demonstration of true television was given by Mr. James Logie Baird of Scotland on January 27th, 1926, in London.

Mr. Baird is the son of a Presbyterian minister at Helensburgh, and has been interested from an early age in scientific research. Some years ago he invented a new form of selenium cell which led up to his interest in television problems. Early in 1925 he gave a public demonstration of the transmission of outlines, by wireless, at Selfridge's shop in Oxford Street, and this was a distinct advance on the shadowgraph transmissions which had previously been attained. He then set out to obtain true television, and his first successful effort was in October, 1925.

Up till then he had been using the head of a ventriloquist's doll as the object to be televised, and at last he succeeded in seeing the doll's face at the receiving end, not as an outline but as a detailed image. He rushed out and persuaded Mr. Taynton, who was then an office boy in the office below, to take the place of the doll before the televisor, but to Mr. Baird's great disappointment nothing at all appeared at the receiving end. He made all possible adjustments of the receiving apparatus, but still nothing appeared, so eventually, feeling very sad and dejected, he went back to the transmitter. There he found that the boy, being bothered by the strong lights used for illuminating his face, had pushed his chair back out of focus. " In the excitement of the moment " says Mr. Baird (who is a Scotsman) " I gave him half a crown to get back into position." This time the face came through all right, but it is interesting to note that the first person ever televised had to be given half a crown for the experience.

The apparatus which was used in these first demonstrations of television can now be seen at the South Kensington Museum under the following inscription :—

"ORIGINAL TELEVISION APPARATUS

MADE BY

J. L. BAIRD.

"This is the transmitting portion of the original apparatus used by Mr. J. L. Baird, in experiments which led him from the wireless transmission of outlines in 1925 to the achievement of true television nine months later, when on January 27th, 1926, the transmission of living human faces with light, shade and detail was demonstrated before members of the Royal Institution, this being the first demonstration of true television ever given."

The following is extracted from a report in *The Times* of January 28th, 1926, the day after the demonstration :

"Members of the Royal Institution and other visitors to a laboratory in an upper room in Frith Street, Soho, on Tuesday saw a demonstration of apparatus invented by Mr. J. L. Baird. . . .

"For the purpose of the demonstration the head of a ventriloquist's doll was manipulated as the image to be transmitted, though the human face was also reproduced, first on a receiver in the same room as the transmitter, and then on a portable receiver in another room; the visitors were shown recognisable reception of the movement of the dummy head and of a person speaking. The image as transmitted was faint and often blurred, but substantiated a claim that through the 'televisor,' as Mr. Baird has named his apparatus, it is possible to transmit and reproduce instantly the details of movement, and such things as the play of expression on the face."

Dr. Alexander Russell, F. R. S., Principal of Faraday House, writing a few months later in *Nature*, July 3rd, 1926, says:

" We saw the transmission by television of living human faces, the proper gradation of light and shade and all movements of the head, of the lips and mouth, and of a cigarette and its smoke, were faithfully portrayed on a screen in the theatre, the transmitter being in a room at the top of the building Naturally, the results are far from perfect. The image cannot be compared with that reproduced by a good kinematograph film. The likeness, however, was unmistakable, and all the motions are reproduced with absolute fidelity. This is the first time we have seen real television, and, so far as we know, Mr. Baird is the first to have accomplished this marvellous feat."

About this time, experimenters in the United States of America were also hot on the trail of television, but the fact that Baird was recognised over there too as the great pioneer may be judged from the following extract from the *New York Times* of March 6th, 1927: " No one but the Scotch minister's son has ever transmitted and received a recognisable image with the gradations of light and shade"; and on February 11th, 1928, the same paper said in an editorial: " Baird was the first to achieve television."

In 1926, the American journal *The Radio News* sent a representative to England to see what Baird was doing. His report in *The Radio News* of September, 1926, stated that "Mr. Baird has definitely and indisputably given a demonstration of real television. It is the first time in history that this has been done in any part of the world."

Other evidence to the same effect could be cited, and the only reason for labouring the point here is that the old saying "a prophet is not without honour save in his own country and in his own house" still holds good, and some writers in this country have seized the opportunity of proving it by trying to show that others had done before what, as a matter of fact, Baird did for the first time on January 17th, 1926, as stated in the inscription in the South Kensington Museum.

Baird continued to give various public demonstrations of television over landlines, including the reception of images in Glasgow from a transmitter in London, a distance of over 400 miles.

In America, the American Telephone and Telegraph Company had taken up the new ideas with enthusiasm and gave a sort of full-dress public demonstration of great interest on April 7th, 1927, over a wire circuit between Washington and New York, a distance of about 200 miles. The most successful images were produced on a small screen two and a half inches square and were described as being comparable to faded daguerreotypes held in a shaky hand. The equipment was very elaborate and costly, and a large staff of engineers was employed at the demonstration. The company, indeed, disclaimed any idea that television on these elaborate lines could have any commercial value.

In January, 1928, the General Electric Company of America gave another elaborate demonstration over a few miles on very similar lines, but the transmission was by short-wave wireless instead of by wire. Baird, however, had also been demonstrating television by wireless, and on February 8th, 1928, he transmitted, by short-wave wireless, the image of a man's face from a room in Long Acre, London, to Hartsdale, a suburb of New York, and in the following month he transmitted images of faces from the same station in London to the *Berengaria* in mid-Atlantic. The ship's officers testified to the excellent reception in the liner. One of the persons whose face was televised from London was the fiancée of Mr. Brown, the chief wireless operator of the *Berengaria*, who wrote in the journal *Television* of April, 1928: "It was a wonderful experience to be able to see Miss Selvey like that in mid-Atlantic, and the achievement clearly demonstrates the enormous progress which has been made in television."

Mr Baird can claim, therefore, to have given the first practical demonstration of television, the first transatlantic transmission and the first transmission to a ship at sea, and apart from these general achievements he was naturally well to the front in various technical developments. Prominent amongst these was an arrangement which he introduced for obtaining synchronism at the sending and receiving ends. This had been a baffling problem from the earliest days, and Baird was the first to produce a satisfactory solution. Early experimenters had found it necessary to use a separate additional wave-length for obtaining synchronism, when transmitting television by wireless, and, owing to the limited number of waves available for wireless signalling, this had been a very serious drawback to the commercial development of television by wireless.

Baird solved this problem by making use of the impulses of the glow-discharge valve of the receiver, by which means he obtained control electromagnetically. His first public demonstration with this arrangement was made over a wire circuit at the Radio Exhibition in London in 1928, and his first public demonstration by wireless was given between the B.B.C. transmitter at Savoy Hill in London and a receiver in the General Post Office on March 5th, 1929. The wireless transmitter, controlled from the Savoy Hill studios, was then located on the top of Selfridge's shop in Oxford Street. At this demonstration only one wave was used for the television and the synchronising arrangement, while speech was transmitted on a different wave.

The success of this demonstration paved the way for including television broadcasts, as an experiment, in some of the regular programmes of the B.B.C.

The first broadcasts of television for the public in this country were made from the London station of the B.B.C. on September 30th, 1929, the television studio being in the London offices of the Baird Television Development Company. The B.B.C. had not facilities at that time for transmitting on two waves simultaneously, so speech was transmitted first and then the image of the speaker. Sir Ambrose Fleming, the veteran scientist who had backed Baird from the start, was the first to speak after the preliminary announcement had been made.

The twin-wave station of the B.B.C. at Brookmans Park became available later, and the first simultaneous transmission of television and sound was broadcast on the 31st March, 1930, and has formed a part of the B.B.C. programme ever since. The television transmission was broadcast on a 261-metre wave, and the sound transmission on a 356-metre wave.

This was an epoch-making event in the development of television. Mr. Sydney Moseley was the announcer, and opened the proceedings with the following remarks:

> " Ladies and Gentlemen,—This inaugurates an epoch in television transmission. For the first time in history we are putting over television simultaneously with sound. I want to explain, as simply as possible, what is happening. I am seated in the Baird studio in Long Acre before a microphone and the television transmitter. My voice is being carried along one line, and the vision along another line to the B.B.C. control room at Savoy Hill. There both voice and vision are connected to the Brookmans Park Broadcasting Stations, where, in turn, they are radiated through two separate wavelengths.
>
> " Those of you who are looking-in should be able to see me as I make this announcement."

And so they did. Television in this country had at last taken its place as a form of public entertainment, but it has still to be developed for commercial use. It had been tried earlier in both Germany and the United States for entertainment purposes, but it has been generally admitted that the first broadcasts in this country were much superior to any that had been given elsewhere; in fact, in America especially the possibilities of television had been boomed so much that there was a great deal of disappointment with the very poor results obtained when it was first introduced to the public. In this country more caution was shown in giving television to the public, as had been the case some years before with wireless broadcasting, and, though we lost any claim to being first in the field, we were saved that feeling of public disappointment which is so apt to clog the development of any new means of communication, especially in a country which does not possess the financial facilities of the United States.

These facilities have already proved of great assistance to the development of television in America. In the early days of telephony it was realised that it would be a great advantage if the speaker and the listener could see one another, and in April, 1930, the American Telephone and Telegraph Company demonstrated the feasibility of two-way telephone conversation combined with two-way television. The system used was called by the company " the Ikonophone." In this arrangement the faces of the persons in communication by telephone are scanned by a beam of mild blue light, by which means they are made visible to one another by television over the line. The telephone booths are lighted by a dim orange light which does not affect the photo-electric cells. The apparatus was, however, complicated and very expensive, but it was a first step towards the aspirations of many pioneer telephone workers.

In May 1930, the General Electric Company of America gave a demonstration of what might be called the first theatrical entertainment by television. An audience of 500 people in a theatre in New York saw and heard an act given in the company's laboratory a mile away. The actors were shown on a six-feet screen by television, and were heard by loudspeakers by wireless. One of the actors, as a variation, came to the theatre after a portion of the play had been shown and played his part on the stage while his partner in the act appeared by television. The pictures, it was said, were quite as good as those produced in the early days of the cinema, but there was a tendency for the picture to sway about on the screen.

Shortly after that, Mr. J. Hammond gave an interesting demonstration near New York of how television may assist an aviator in seeing a landing-place in thick weather. It was claimed that he could see an image of the landing-place, and would have no difficulty in alighting. But this brings us to another of Mr. Baird's inventions, the Noctovisor, by which he demonstrated the possibility, so to speak, of seeing in darkness or fog.

Baird made this discovery in 1926. It consists of using infra-red rays of light for illuminating the object, instead of using the ether rays between violet and red which affect the eye by what we call light. Ether waves just longer than those which affect the eye as red light are called infra-red waves, or rays. These rays do not affect the eye, but Baird found that they could be used in television transmission in place of visible light rays, so that it was possible to televise an object in darkness. These infra-red rays are able to penetrate fog much better than visible light rays, and when noctovision is developed it will undoubtedly be adapted to navigation. A ship in a fog, for example, will be able to direct a beam of infra-red rays, just as a searchlight is directed, but instead of the object being seen by the eye, as it would in clear weather, it will be shown on the screen of a noctovision receiver. Indeed, it is apparent that all sorts of possibilities will be opened when noctovision is developed commercially. Baird's first important demonstration with noctovision was given to members of the Royal Institution, London, in December, 1926, and he has since given several successful public demonstrations. The invention, however, has not yet been developed for commercial use.

There is nothing new, of course, in the fact that these infra-red rays are specially suitable for penetrating fog, as it is well known that the penetrative power of light varies as the fourth power of its wavelength, red light being about sixteen times better than blue light for penetrating fog. Use is made of this phenomenon at aerodromes where the deep red glow of Neon tubes is used for guiding airmen on account of its fog-penetrating power. These rays, too, were used in the War on certain occasions for signalling purposes in place of visible light, but Baird was the first to make use of them in connection with television.

Another interesting arrangement, called Phonovision, has been developed by Baird. Phonovision is a method of permanently recording the image sound. We have seen that in television the light reflected from an object produces, through the agency of photoelectric cells, variations in the strength of current in the line, or, in wireless, variations in the waves transmitted. These variations can be heard as variations of noise in the ordinary way on a telephone receiver ; in fact, it is possible to distinguish even the differences in noise made by two faces at the sending end. Every movement, too, such as opening the mouth causes a change in the noise. Now, these noises, or sounds, can be recorded permanently on a phonograph, and if the record is played into a microphone connected to a televisor, working in synchronism with the phonograph, the original image can be reproduced. This original image is thus made to produce variations in current, which are converted into variations in sound, which produce indentations in wax. The process is then reversed at will, and the image reproduced. It is easy to see that many interesting possibilities are opened up by phonovision, and it has even been suggested that blind people will be able, some day, to recognise people by the sound of their faces. But phonovision has not yet been developed on a commercial basis, and it would be idle to discuss possibilities which, at the best, could be little more than guesses.

A spectacular advance in television from the entertainment point of view took place on July 28th, 1930, when television was shown for the first time as a turn in an ordinary variety entertainment. This was carried out by the Baird system at the London Coliseum. A large ground-glass screen was placed on the stage. Behind the screen was a honeycomb arrangement with 2,100 compartments in each of which was a small metal filament lamp connected to a segment of a commutator which was made up of 2,100 segments. As the brush of the commutator revolved each lamp was lit up in turn, so that the whole screen was scanned in one revolution of the brush. The television signal which was received over landlines from the Baird studios, where the performers were situated, was amplified and the output fed each lamp in turn, the amount of brilliance of the light from the lamp depending on the strength of the current which in turn depended, in the ordinary way, on the intensity of light at the sending end. The images on the screen of the performers in the studio were quite recognisable, and loudspeaker connection was arranged in the Coliseum so that the audience could also hear the performers speaking.

Television will doubtless develop into a most important means of electrical communication, but it seems likely that it will first be developed for entertainment purposes.

In the United States, at any rate, plans are now being made on a large scale for its development on the lines of amusement. It is proposed to construct in New York a huge theatrical building. Here there will be accommodation for variety theatres, theatres for the legitimate drama, concert halls, comedy theatres, talking pictures and facilities for television. It is hoped ultimately to distribute by television and wireless, plays, church services, etc., to the homes of the people. Here we are progressing on less ambitious, or, at any rate, less grandiose, lines, but enough has been said in this book on the development of electrical communications to show that, whatever the future has in store, we may be quite sure that the Old Country will be well up in the front line.

CHAPTER XXIV

SOME PERSONAL REMINISCENCES

MY introduction to wireless telegraphy (no mention of "radio" then) was at a lecture by the late Monseigneur Molloy in Dublin, in the summer of 1898. Signor, now Marchese, Marconi was present, and he has told me since that it was the best popular lecture he has ever heard, so it is no wonder that I caught the disease on the spot, and have suffered from it ever since. All I remember of the lecture is that a wireless message was transmitted in the lecture hall and received by a coherer on a tape. The Lord Mayor of Dublin, who presided, was given the tape, and, turning to the audience, said, "there is divil a message I can see but a lot of dots and dashes."

A couple of years later the Admiralty sent some sets out to the Mediterranean fleet, and I was told off, with another officer, to rig up a set in our ship. The struggle lasted several days, and in the end we were defeated, as the coherer resolutely refused to respond to the buzzer, though it worked gleefully with the wet fingers' test on the jigger's terminals. At last we had to send for help from a petty officer of Commander Jackson's ship, the fount of our wireless knowledge. To our disgust, he severed our carefully made connection between the aerial and earth terminals of the buzzer, and all was well!

But those were days of high romance and adventure, when you connected up one part of a circuit to another on the off chance that something would happen, and it often did happen forcibly as those, too, were the days of "plain aerial" transmission. I well remember one of the first times I connected up the aerial to the spark gap, as my friend chose the same moment for adjusting the key. But we renewed our friendship next day. I remember, too, seeing a bluejacket play his hose on the aerial when washing down ship. We were signalling on "plain aerial" and his language, as he dropped the hose pipe, was extremely entertaining.

In those days we disliked on principle all signal officers, as they were always fouling our beautiful aerials with their silly flags; but we knew when they were up to their tricks as our plain spark failed, and we sometimes got our own back in wet weather when a signalman touched the halliards. Later on, when tuned transmitters came into use, they had it all their own way, as we seldom knew when their flags were fouling; so to win them over to the importance of wireless we had to resort to flattery on the importance of "bunting tossing."

As a matter of fact, in the early days the "bunting tossers" often established communication long before the "wireless experts" had got beyond the stage of exchanging V·s.

It was wonderful how a coherer receiving set, which refused to produce one word of a message, would cheerfully print strings of V's from the same source without a mistake when the receiving operator moistened his fingers and tickled it up at the right moment. Why it was I do not know; but those who have struggled with coherers will bear me out.

Marconi, being more original, said: "Well, what have you got?" And the attendant replied: "I have eggs and bacon, sor." "Have you anything else?" inquired Marconi. "Indade, and I've not," came the reply, followed up by an indignant "and what more can ye be wanting, anyway?" So Marconi joined in with the rest of us, and an excellent breakfast it was, very welcome to me as it had been a bad passage, and I am no sailor in anything smaller than a battleship.

It was while on a visit to Poldhu that Marconi first demonstrated his discovery of the directional effects of low horizontal aerials. We all had dinner together at the hotel, which is a few hundred yards distant from the wireless station, and when the table had been cleared Marconi placed a magnetic detector, with headphones for each of us, in the centre of the table. He connected one end of a piece of wire, a few feet long, to the aerial terminal of the instrument, and holding the other end just clear of our heads, walked round the table. When the wire was in the direction of the station which was transmitting, we heard loud signals, and when it was at right angles to that direction we heard nothing. Personally, I was amazed, and I consider this to have been the most impressive demonstration I have ever witnessed. Next day we had a full-dress demonstration with real aerials in the open country; but Marconi had shown us all that there was to be shown in those two minutes at the dinner table. I remember we looked wise and asked him for explanations. He told us that he had not had time to consider explanations, but that Dr. Fleming, in London, was tackling that part of the business!

It was on the same visit that he showed us the reception of signals on apparatus which he had carefully locked up in a box, and which he could not then disclose to us.

The reception was excellent and we very curious; but it was not till the Fleming valve patent was published some months later that we knew the contents of what we had christened " The locked box of Poldhu." In those days there was much secrecy about the apparatus used at large stations, and visits from Government officials were not always welcomed. In 1906 I was detailed by the Admiralty to accompany the late Sir John Gavey, of the Post Office, on a visit to a station erected by an American company, using Fessenden's patents, for transatlantic communication, at Machrihanish in Scotland.

The polite engineer-in-charge was so sorry that the station was out of action, and that, in fact, most of the apparatus was dismantled, facts very apparent from the hasty inspection which he permitted us to make on arrival. Next day we hoped to see more, but the dismantling process appeared to have progressed rapidly even during the night, so we decided to accept defeat and allow ourselves to be taken by the engineer to a picnic which he had thoughtfully arranged for us some miles away.

This Machrihanish station, which established communication nightly in 1905 with Brant Rock, 3,000 miles away, was a remarkable venture, as the steel mast, 415 ft. in height, was brought over in sections from the United States of America and erected on an insulated base in a few weeks. The installation, of about 25 k.w., was working in a few weeks more with a distinctive musical note, and its signals, which I often listened to at Gibraltar, were, I thought, superior in every way to those being sent from Poldhu. It have limits, and we lost a beautiful, if expensive, "earth."

In the Mediterranean we came into contact pretty frequently with foreign navies, and I remember a night when one of their officers spent the whole of dinner in explaining to me what wonderful results they were getting with wireless telephony. I was greatly impressed, as we ourselves had nothing of the sort at that time. A year later we dined together again, and he reminded me of the pleasant time he had had in pulling my leg on the previous occasion! But I got a bit of my own back the next day. He invited me and some others to come and see round his ship. He showed the party round, but I lost them and walked into the wireless cabin. The operator tried to persuade me to go out, but he spoke in a language which I did not understand. I had a pleasant quarter of an hour examining their arrangements in detail, until my friend found me just where he feared I was and told me quite clearly in a language which I did understand that no foreign officer was allowed inside their wireless cabin under any conditions whatever. I was duly contrite, but it was no use, as he knew me too well, so all he did was to ask me to lunch.

The first time I tried wireless telephony was in the *Defiance* at Devonport in 1911 with an arc transmitter in the sending, and a Brown relay in the receiving, circuit, but I never got much more than a few muffled words and snorting sounds after weeks of trial.

In 1912 I was lent to the Post Office to assist in selecting sites for stations for the Imperial Chain, in Egypt and Kenya. As regards wireless telegraphy, what impressed me most in Egypt were the caustic remarks of the Military Commander-in-Chief, now Lord

Byng, when he came to see our transmitting site, and found but a desert and a three hours' wait for the next train to Cairo. Our receiving site was even more so, as it was in the same old desert but further from Cairo. Luckily the General expressed no desire to visit it. I was asked to send home a photograph of this latter site but I had not got one, so sent an excellent substitute, a blank sheet of paper headed " View of site facing N.S.E. or W."

In Kenya Colony, the predominant features from a wireless point of view are atmospherics and mountains. Both are huge, and both are most disturbing to the site-hunter.

Talking of hunting reminds me of our grand lion hunt. We set off in the early morning on a lion's trail with a pack of dogs and a retinue of porters, gunbearers, and hangers-on of all kinds. Tartarin wasn't in it with us. We returned in the evening with the same retinue and the spoils of our hunt—a young partridge! But we had other thrills. One night, my friend and I turned in on opposite sides of our capacious tent. We were replete with lion stories, so I had a loaded rifle beside me, and he had a loaded revolver. Now, I heartily dislike anyone but myself with a revolver, as no weapon can go off so easily and unexpectedly, and my friend quite as heartily disliked the combination of a rifle and me. In the dead of night a large beast came into the tent, and stood between us—I suppose for seconds, though it seemed for hours—as my friend and I lay breathless, he thinking of my rifle, and I of his revolver. I guessed rightly that it was one of our dogs, and so did he; but neither knew what the other was guessing, and I shall never forget my relief when that old dog turned tail and stalked out again.

As for atmospherics, I thought the highlands of Kenya must be the worst place in the world, until I went farther west into Uganda where they had to earth the telephone system daily from 2 p.m. till the following morning. If there really is a worse country than Uganda for atmospherics I should like to hear of it, but I have no desire to see it. I have supervised the working of land stations in the West Indies, South America, West Africa and the Azores, but for atmospherics none of them is comparable with Uganda.

In Jamaica, in the West Indies, we had a cyclone just as the station had got into nice working order; the roof suffered badly, and for two days and nights we paddled about in sea-boots, with umbrellas up, stopping up holes in the roof and covering the plant with rugs, mats, blankets, etc.; the two most uncomfortable nights I have ever experienced. It was worse than listening to jazz music from America at 3 a.m.

There is always difficulty in keeping one's stores intact abroad, and Jamaica was no exception. I had drawn most of those most useful to the natives, such as digging and tree-felling implements, from naval stores, and frequent losses got me into trouble with the stores officer, until I found out that "lost overboard" covered a multitude of sins. The station, I may mention, was in the centre of the island. That reminds me of the first position of an enemy submarine which we located by D.F. stations in the Azores, and unfortunately reported, by mistake, to the Admiralty. It was a good clear cut, and placed the submarine right in the centre of Spain.

At the beginning of the War I went to the Grand Fleet for wireless duties. I left London on the night when we first had news of the arrival in England of the phantom Russian troops, and told the story the following night to an army officer at the hotel in Kirkwall in the Orkneys. Next morning when the "boots" called me he told me that the military authorities had had official information of the arrival of a Russian army in England—not a bad expansion for one night!

We had plenty of excitement in the Fleet in those early days of the War, as, judging from reports (as authentic as those of the Russian army), the whole of the enemy's submarine forces, and more, seemed to be concentrated at the Orkneys; indeed, the night I arrived an enemy submarine was reported in the harbour, and the whole fleet cleared out to sea on the spot. One day, we intercepted a wireless signal from our cruisers ahead to the effect that they had sighted enemy cruisers. We thought "the Day" had come, cleared for action and donned our disinfected uniforms. But we also intercepted a second signal cancelling the first one, so we had our lunch in peace. Some ships intercepted the first signal but missed the second, and remained on tenterhooks all the afternoon.

Later in the War when the German submarines got busy with our merchant ships, a demand arose for wireless operators to man the huge fleet of small craft which were required to combat this new menace. I was sent to take charge of a training school at the Crystal Palace in London to produce the operators required. When we got going properly we had 1,200 R.N.V.R. men in the school, and were drafting 200 a month to the Navy. I think this must have been the largest wireless school ever formed. The wireless course was only three months, and the men passing out had to be able to send and receive at twenty words a minute, and to possess sufficient wireless knowledge to act as operators in a small ship. I rather think that this was a record too, but we had the best type of man to work on, and no scruples about an eight-hour day.

No reminiscences are complete nowadays without a few kings and queens in them. I cannot oblige with queens, as I have only been presented to one, Queen Alexandra, and we did not get as far as wireless conversation ; in fact, I doubt if I progressed past the bowing stage. But I was once honoured by the presence of her husband, King Edward, and King Alfonso, with their staffs, in the wireless cabin of a ship at Malta. It was a very small cabin, suitable for no more than two persons at a time, and was situated next the ward-room pantry, where lunch was being prepared. The lunch was apparently to consist partly of onions, so that the interview was shorter than it might otherwise have been. Both kings gave me a message to send on to Gibraltar, but neither they nor their staffs showed any desire to remain longer than was absolutely necessary.

King George I of Greece, brother of our Queen Alexandra, visited the same cabin on another occasion, more propitious from the point of view of the ward-room pantry. I was astounded at his knowledge of wireless telegraphy, especially as to the advantages of C.W. transmission, until I remembered the name of another famous countryman of his, M. Valdemar Poulsen of Denmark. Some days later the king entertained a number of us to lunch at his country residence near Athens. He was a great cigar-smoker, and after lunch requested us to put our cigar ends in his tray, a huge glass bowl, about 18 in. in diameter, explaining that anything smaller in the way of an ash tray was of no use to him.

A few weeks later I was at a similar though very different function, a banquet given by Abdul Hamid, Sultan of Turkey, at his palace, Yildez Kiosk. It was a very gorgeous affair; everything seemed to be made of gold, except, happily, the blades of the knives. Behind each chair stood a richly attired, ferocious-looking gentleman with a drawn scimitar. It gave one quite an Arabian Nights sort of feeling that if the Sultan got displeased one's head might be chopped off at a moment's notice. There were two ladies at the dinner, an almost unheard-of occurrence, so my Turkish neighbour informed me, and I was told afterwards that, in honour of the occasion, one of the ladies was invested with the Turkish Order of Chastity, 1st Class. That was all right, but the other, so I was told, received the 2nd Class of the same Order. But I hope not.

INDEX

Printed for the Publishers
at the BURLEIGH PRESS, *Lewin's Mead*, BRISTOL.