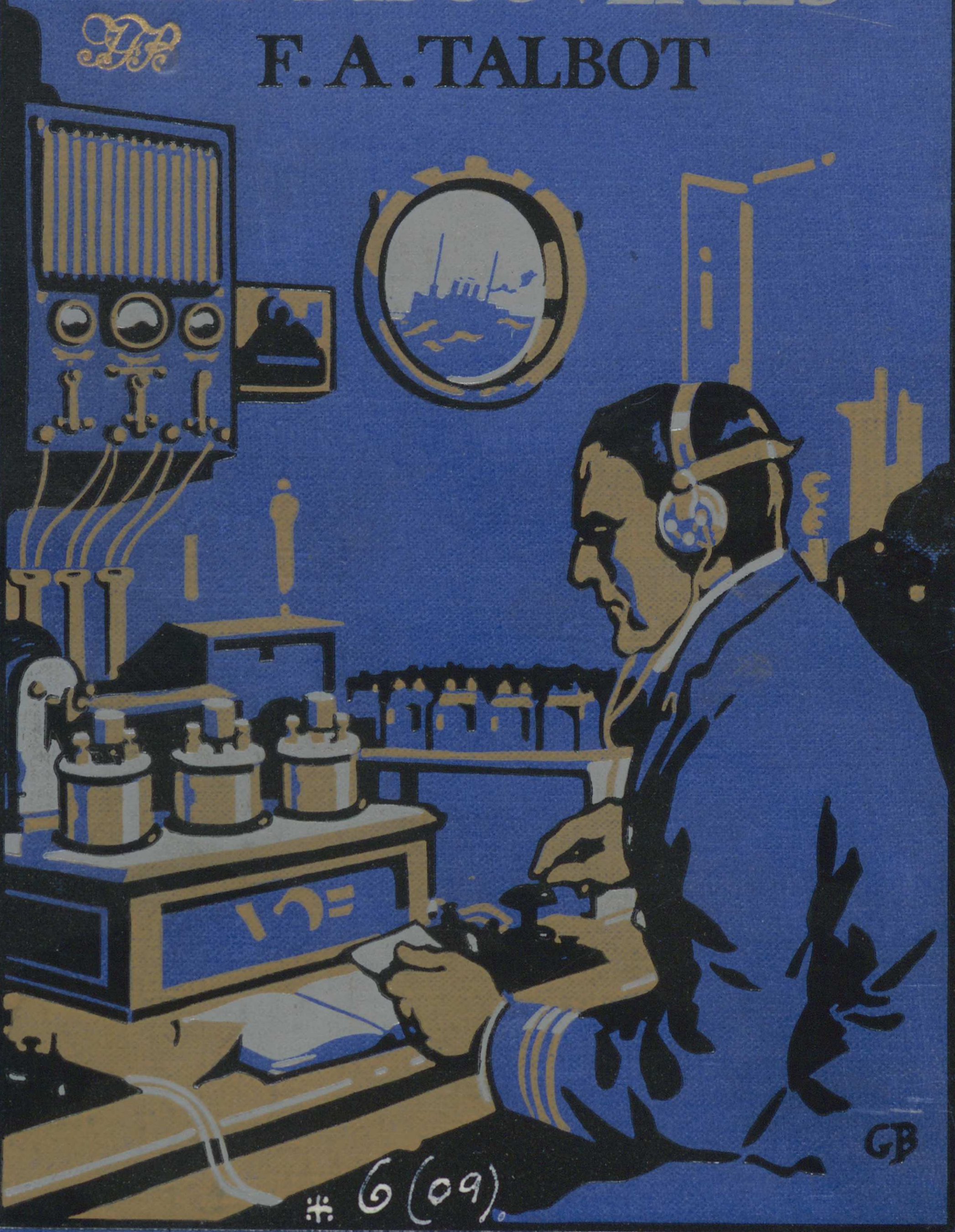
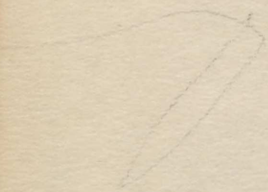
ALL ABOUT INVENTIONS AND DISCOVERIES

F. A. TALBOT





SPEED!

A race between a tractor biplane, an electric train and a high-power motor-car, illustrating three great speeds attained by mechanical invention.

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THE ROMANCE OF MODERN SCIENTIFIC AND MECHANICAL ACHIEVEMENTS

BY

FREDERICK A. TALBOT

Author of "Railway Wonders of the World," "Moving Pictures," "Oil Conquest of the World," etc. etc.

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First published 1916

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CHAPTER I

Wireless Telegraphy

VISITORS to Sunny Italy during the year 1895 who wandered among the picturesque sylvan homes fringing the city of Bologna had their curiosity keenly aroused when passing a particular villa. In the grounds were a few poles or masts of varying heights, each of which carried an unpretentious tin box. The picture was somewhat quaint, recalling nothing so much, perhaps, as the cleared patches surrounding an aboriginal village in the forest, where branch-stripped trees are bedecked with small unsightly wooden receptacles perched high above the ground.

These poles and tin boxes not only aroused the attention of travellers, but puzzled the neighbours as well. To them their purpose or object was equally inscrutable. And their wonder became accentuated when they made a surreptitious closer investigation, because they found thin wires trailing from some of the tin boxes, the lower ends of which disappeared into a small outbuilding.

The more intimately acquainted and the courageous, unable to stifle their inquisitiveness, sought an explanation of the mystery from the gentleman to whom the villa belonged, but he could not gratify their whims. All that he could say was that his son, a young man of twenty-one, was deeply interested in electricity. Some new idea or other had occurred to him, and he had set up these poles and tin boxes to prove or disprove, from practical experiment, certain theories which he had evolved.

As for the young investigator, he pursued his studies and investigations unperturbed. Throughout the day he was seen dodging among these poles, making some adjustment to this box, and altering the position of that. At night the neighbours observed that the lights in the outbuilding burned to a late hour. Evidently the young man was hot upon the trail of something, judging from the diligence with which he laboured, and the long hours which he toiled.

After some weeks probing and moving among these poles and buildings the young Italian wrote to one of the foremost British telegraphic authorities communicating the results of his observations and labour. The young correspondent was quite unknown to the expert, but the letter aroused the latter's interest to an extreme degree. He himself had been conducting some inquiries in the selfsame direction, but the industrious Italian youth evidently was able to reveal something of considerable moment, because the electrical expert replied without delay.

The correspondence was continued for a week or two, and then the British electrician extended an invitation to his Italian enthusiast to come to London. This was the opportunity for which the young experimenter had been waiting. He accepted it with alacrity, and a day or two afterwards was immersed in a deep and prolonged conversation with the electrical authority. This heart-to-heart chat was profoundly fruitful, and the British engineer was so favourably impressed and interested that he turned over his laboratory to the Italian worker and urged him to continue his experiments with all the zeal he could command.

The young Italian experimenter was Signor (now Commendatore) Guglielmo Marconi, while the interested patron was Mr. (afterwards Sir) William H. Preece, chief electrical engineer of the telegraph system of the General Post Office. It was not long before the mystery surrounding the tin boxes and masts or poles in the grounds of the gentleman residing in Bologna was cleared up. They were "capacities," and they were connected by wires to primitive instruments which young Marconi had contrived with his own hands.

Marconi explained to chief-engineer Preece that when he set the capacities about 6 feet above ground he could send signals through the air, and without wires, over a distance of 100 yards. When he elevated the tin box at the sending station to a height of 14 feet the signals could be received approximately 300 yards away, and so on. The point which the experimenter desired to emphasise was that the higher the mast and the position of the capacity above the ground, the greater the distance over which signals could be sent successfully through the air. In fact, he himself, with his crude facilities, had been able to maintain communication in this manner between two points a mile and a half apart.

Naturally these achievements aroused intense interest among those to whom the results were communicated. And when Marconi repeated the experiments in the laboratory, to the satisfaction of Sir William Preece and other scientists, they were received with such emphatic favour that it was decided to carry out further trials without delay in the open air. The comparative security of Salisbury Plain was selected as the most favourable spot, and here the results were repeated without the slightest interference or publicity. But these trials proved additionally remarkable, because it was found possible to send the signals through houses, hills, and other obstacles with as much facility as over a stretch of the open level plain.

Moreover, the influence of the height of the capacity above the ground upon distance was brought home very strikingly, and forthwith it was decided to determine how far such signals might be sent with the instruments available. In order to elevate the capacity to a sufficiently imposing height weird and novel efforts were made. Tiny balloons covered with tinfoil, and kites of varying forms and design, similarly covered with tinfoil, were sent aloft, a thin wire being used instead of the conventional string, and connected to the instruments upon the ground below. This work proved somewhat exasperating, because the fickle Clerk of the British Weather would persist in intervening, and appeared to be striving desperately to thwart the realisation of the young Italian's dream. Balloon after balloon was wrenched free and hurried away in mad glee by the boisterous winds, never to be seen nor heard of again. Kites were ripped, torn, and smashed by the same rebellious force with galling frequency. But notwithstanding these maddening interruptions Marconi stuck to his task, and finally enjoyed the satisfaction of being able to transmit his signals through space from one station to another four miles away.

The success was complete. The ability to maintain conversation by the dots and dashes of the Morse code through space and without the assistance of connecting wires was established conclusively. Now it was merely a matter of development, improvement of details and instruments, and this work could only be satisfactorily accomplished by unremitting experiment. Signor Marconi, having convinced his friends and having secured the necessary financial and technical assistance to consummate the desired end of being able to talk round the world if necessary, resumed his experiments with redoubled energy. Wireless telegraphy had been lifted out of the rut of laboratory experiment into the channel of practical utilisation.

It has been asserted that Signor Marconi did not invent wireless telegraphy. From the pedantic viewpoint this contention may possibly be correct. In 1887 a German scientist, Heinrich Hertz, startled the scientific world by announcing that he had succeeded in sending invisible electro-magnetic waves through the ether with the velocity of light waves—that is, at the speed of 186,000 miles per second. Hertz had been attracted to this field of endeavour by those famous British scientists, Michael Faraday, Thomson and Clerk Maxwell. These three experimenters did not carry their researches to their logical conclusion, but merely indicated the broad path for future investigation, which Hertz followed. His work was thorough and conclusive.

His achievement was so sensational as to stimulate scientists throughout the world. One and all picked up the threads of research at the point to which they had been carried by Hertz. Now the curious point is that the German philosopher had no idea of applying his discovery to the conveyance of signals, corresponding to sounds, through the ether. He pursued the subject in the effort to solve the problem of light, and at the time his results were considered to be the most valuable contributions to this subject.

The term ether is one which is misunderstood by the average individual. Generally speaking, it is assumed to be a synonym for atmosphere, but this is a serious mistake, as it has nothing to do with the atmosphere surrounding this earth. As is well known, the air we breathe constitutes a layer or invisible blanket covering this globe which, as one ascends, grows thinner or rarer in its composition, until at last, at a certain height, it is no longer encountered. But from the edge of our respirable air to other worlds a certain subtile medium exists which fills all the apparent empty space. This is the medium which scientists have designated ether. More than this, it is claimed to permeate all matter even in this atmosphere-covered sphere. That this is so was demonstrated by Marconi when he sent his signals, corresponding to the dot and dash of the Morse alphabet, through hills and buildings upon Salisbury Plain, although the selfsame phenomenon had been previously observed in the laboratory.

Now these electro-magnetic waves, when thrown into the ether, behave in a manner precisely similar to a stone flung into a mill-pond. As the stone produces a series of ripples or waves which travel across the surface of the pond in regular circles until they either strike the banks or become weakened to such a degree as to become invisible, apparently exhausting themselves, so do the electric waves radiate through the ether, the point at which the electric force is discharged corresponding with the spot at which the stone strikes the water. Moreover, as the water ripples grow weaker as they travel, so do the electro-magnetic waves, the result being that a delicate instrument is required to detect and to trap them.

The arrest of these electro-magnetic waves occupied the attention of many notable scientists. Two, French and British respectively, attacked the problem, but independently and unknown to each other, and both achieved success. The Frenchman was Monsieur Edouard Branly, and the Britisher Sir Oliver Lodge. What is more remarkable, the devices which each contrived were broadly alike, at least in principle. They took a small length of tube resembling that in which the mercury is contained for a thermometer. At each end of this tube a small plug was inserted. The wire leading from the "capacity" aerial, or antennæ, to quote its different terms, which was placed upon a mast, and upon which the electro-magnetic waves impinged and were collected during their journey through the ether, was carried to one plug. From the other plug a second wire extended to an instrument. This arrangement left a short gap within the tube. Now the electro-magnetic wave is too weak to jump this gap, so a means of bridging the breach was introduced. Within the tube were placed extremely fine particles of silver and nickel. They are so fine as to pass through the almost invisible meshes of a piece of silk. These filings, when inserted within the tube, which was disposed horizontally, rested in a loose heap upon the lower surface of the glass, in precisely the same way as they would lie upon a piece of paper on a table.

When the electro-magnetic wave, striking the capacity placed upon the mast, travelled through the wire it encountered an interruption at the plug in the tube. It could not jump the gap to continue its passage through the wire extending from the other end of the tube, because it was too weak or exhausted. But the ether permeates all matter, and is as present in the tube as above the layer of atmosphere enclosing this earth. Consequently it continued its passage, and in so doing magnetised each particle of dust lying within the tube. The result was that the particles clung to one another as a collection of tin-tacks will crowd to the poles of a magnet, and in this way they formed a bridge between the two ends of the wires terminating in their plugs at either end of the tube, so that a continuous metal path was provided from the capacity to the instrument. This means of detecting the electro-magnetic waves proved highly successful owing to its extreme sensitiveness. The faintest wave was sufficient to induce the particles to fly and to cohere together, and from this quality the apparatus became known as the "coherer."

But there was one drawback. After the particles had been magnetised and, cohering together, had formed a bridge through the tube, they maintained that position even when no current was flowing. Consequently it became necessary to break the bridge after the wave had passed. This was a simple matter. It was only necessary to give the tube a sharp, slight jar or knock to induce the particles to fall apart. In the earliest days this was done by striking the tube sharply with the finger. Later, to facilitate the operation, a small hammer-like device was introduced which, striking the tube after the wave had passed, broke the bridge. This tiny hammer was operated by clockwork mechanism, and from its function became known as the "tapper-back," because it reduced the dust particles to their original independent condition, or "decohered" them, as it was termed.

In 1895 another far-reaching improvement was made by the perfection of an automatic tapper-back by Professor A. Popoff, of the Russian Torpedo School at Cronstadt. But here again an invention was devised for a purpose quite away from wireless telegraphy. This scientist was deeply engaged in the study of lightning phenomena, and he evolved an interesting instrument for observing these electrical discharges. He took the coherer and combined with it a relay, recording mechanism, and the tapper-back. By means of this ingenious instrument he was able to record automatically upon a strip of paper the time of each lightning flash. More than this was rendered possible. After a flash had been received and recorded the instrument automatically reset itself for recording the next flash. The relay actuated the tapper-back, which, striking the tube, decohered the particles. This ingenious instrument successfully solved a problem which had been perplexing several minds for many years, because thereby it was rendered possible to detect each succeeding electro-magnetic wave, with the relative interruptions between.

But up to this time no attempt had been made to apply the discovery of Hertz to a commercial purpose. Signor Marconi realised this fact, and he accordingly devoted his energies to contrive ways and means to this end. He set himself to the solution of one definite task—the transmission and receipt of wireless signals through space by the Morse code. In order to achieve his purpose he was necessarily compelled to embrace the work of other investigators, such as the incorporation of the coherer, which was the only known means of detecting the ether waves in those days; but at the same time a considerable amount of his work and instruments were of a pioneer character, and the fruits of his own thought and handiwork. Marconi was the first man to assemble the pieces of a scientific jig-saw puzzle in such a manner as to enable one to telegraph without wires, and for his success in this direction, and the correct commercial application of certain phases of previous knowledge, he is entitled to the honour of being called the inventor of wireless telegraphy. The Germans, with the Telefunken system, sought to deprive him of this distinction, but throughout the rest of the world the Teuton contention receives scant attention.

At the same time it is only fair to remark that other scientists, once their attention had been drawn to the possibilities of wireless telegraphy, attacked the problem energetically, and some of these diligent toilers have contributed in no small manner to the present success of etheric communication. Among these may be mentioned Sir Oliver Lodge and Dr. Muirhead, Professor Fessenden, Professor Fleming, Dr. Valdemar Poulsen, and Mr. Lee de Forest.

Owing to the success of the trials upon Salisbury Plain, Signor Marconi removed his field of further experiment to the Isle of Wight. During the latter part of the year 1897 he erected a mast 120 feet in height near the Needles. Then he took a tug and, fitting it with a mast 60 feet in height, put out from the Isle of Wight, running a course towards Bournemouth on the mainland. As the tug moved forward the transmission of signals from the Needles station commenced. The object of this investigation was to determine how far from the Needles the signals dispatched from that station might be picked up, the great ambition being to link the island with the mainland by wireless.

Progress was slow, although Marconi and his assistants toiled day in and day out, irrespective of weather. Slowly but surely the little vessel crept farther and farther away from the Needles. Suddenly there would be a pause. The signals which had been coming regularly ceased without warning. Thereupon the instruments within the tug were adjusted, and improved details made here and there. Once again the signals rolled in, and again the tug moved ahead, continuing its snail-like passage until another breakdown in the receipt of the signals came, when the vessel was eased up and further improvements effected. The work was tedious, while tossing about in a small tug upon the rough bosom of the Channel during the blusterous and cold winter months was by no means envious. The weeks slipped by, too rapidly for the inventor and his colleagues engaged in the common quest, but there was this one satisfaction : the Needles were falling farther and farther behind, while the mainland was looming nearer and nearer.

At last the tug reached the mainland : the Solent was spanned by wireless ! True it was only a matter of fourteen miles between the points as the crow flies, but it was a startling achievement for those days. The distance was afterwards increased by establishing the permanent experimental station at Poole, lower down the coast, the gap through the air thus being eighteen miles.

But the ability to communicate through space across the Solent incidentally led to the first commercial recognition of wireless. Needless to say, newspaper enterprise was responsible for this development, but it was not a London paper which gave this stimulus, as might be supposed. The fact that Marconi had been able to send and to receive messages from a moving station as represented by the tug moving across the Solent impressed the editor of the *Dublin Daily Express*. The Kingstown yacht regatta was to be held in July, and the editor decided to essay a scoop over his rivals, and sought the assistance of the Italian wizard. Marconi accepted the invitation, and accordingly a mast 110 feet in height was erected at Kingstown, while an aerial was stretched from the mast of the s.s. *Flying Huntress*, which was specially chartered for the occasion. As a result of his preliminary experiments Marconi entertained no apprehensions concerning his ability to fulfil the editorial desires, because he found it quite an easy matter to maintain communication with

Kingstown from any distance up to twenty-five miles, which was the maximum attempted.

The reporting of the regatta by wireless proved an astonishing success. The *Flying Huntress* accompanied the vessels, and meantime sent a continuous string of messages to Kingstown describing the races. Upon receipt at Kingstown they were telephoned direct to the editorial rooms of the newspaper, and the Dublin readers had the novel experience of following the races while they were actually in progress, and when the vessels were out of sight of land. The enterprise of the *Dublin Daily Express* met with the success it deserved, while it indicated, for the first time, one of the fields in which wireless might be utilised profitably.

Hot on the heels of this success came another appreciation. His Majesty King Edward VII., then Prince of Wales, had the misfortune to meet with an injury to his knee which demanded a period of complete rest, and he was transferred to the Royal yacht for medical treatment. Queen Victoria, in order to keep in touch with the yacht, called upon Marconi to provide a wireless communicating link between the vessel and Osborne House. This installation brought the invention very prominently before the Royal Family, the floating station, the instruments of which were accommodated in the saloon, being a never-ending source of interest and wonder to the august visitors to the yacht during the royal invalid's indisposition.

While Marconi was meeting with success on every hand, he was toiling as assiduously as he had done a few years previously upon his father's estate at

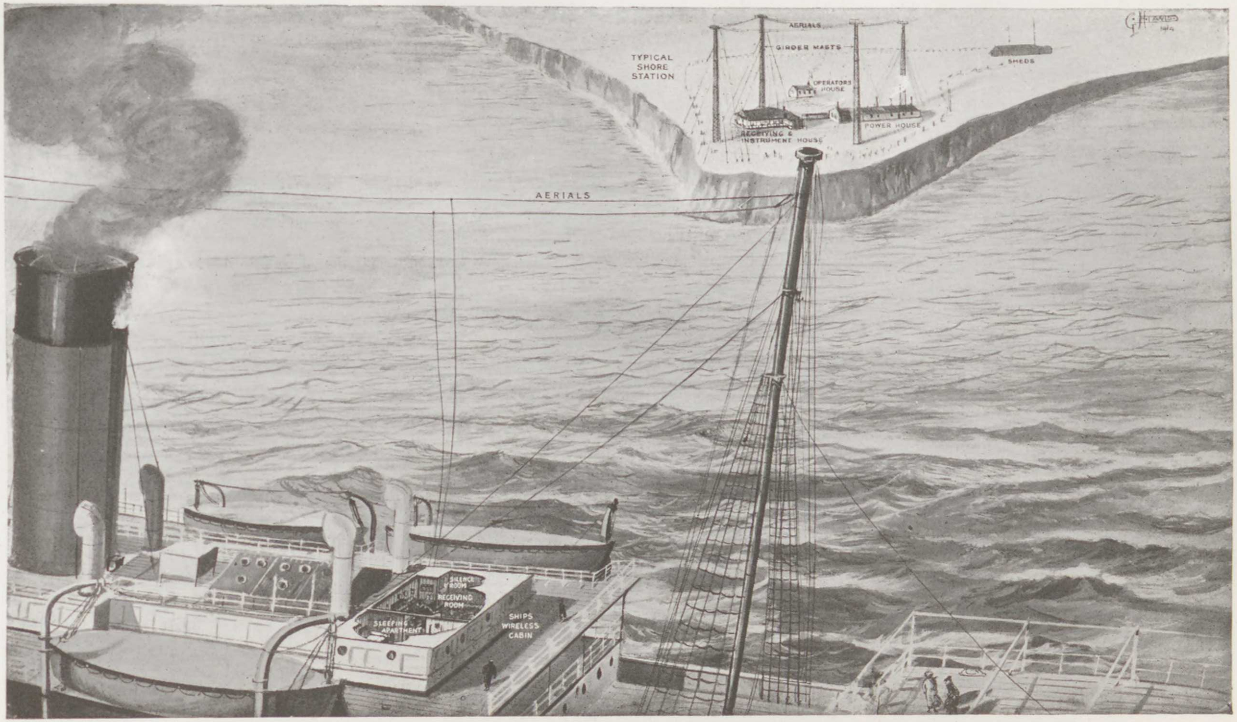
Bologna. With each successive development and improvement, new possibilities and technical questions arose. When Marconi first communicated with Sir William Preece he emphasised the fact that the distance over which communication might be maintained varied according to the height of the mast. By the time the Solent was bridged the law governing the range of distance appeared to be the square of the mast's height. That is to say, if the mast were increased from 80 to 160 feet, a message could be sent with the latter up to eighty miles as compared with twenty miles with the 80-foot mast, while if the mast were made 240 feet in height then the message could be sent 180 miles, and so on. According to this principle of calculation it would demand a mast about 1,000 feet in height to send a message from London to New York. Now, naturally, the erection of such a mast would not only be highly expensive, but it would be costly and difficult to maintain. Accordingly, Marconi concentrated his efforts upon the revision of this law, if it were at all possible. By improving his instruments at the Needles and Poole stations he discovered that he could use lower masts, and within a few months of bridging the Solent he had actually reduced the height of the mast at the Needles by one half—from 120 to 60 feet. The possibility of being able to bring the height of the mast down to a convenient point was only one field for further investigation which was opened up as a result of these later researches and experiments, but one and all contributed very materially to the efficiency of the system and its commercial value.

The claims of humanity now became centred upon wireless. It was realised that this system of communication would prove of inestimable value in the warning of ships during foggy and thick weather. The Brethren of Trinity House, the Corporation responsible for the lighthouses and lightships dotted around the English coast, decided to fathom its possibilities in this direction. The Goodwin Sands are one of the most sinister spots among the waters washing our shores, and it was a point where wireless, as applied to the seas, might be subjected to its most exacting trials. The mast of the East Goodwins lightship was extended to a height sufficient to ensure continuous communication with the shore station set up on the South Foreland, twelve miles away. At the latter point the mast, 150 feet in height, was set up on the edge of the towering cliff.

Wireless in connection with the sea was soon subjected to the test and triumphed. When a vessel was observed from the lightship to be in distress, warning was flashed to the South Foreland station. From this point it was merely a matter of telephoning to the adjacent lifeboat stations to secure the ready assistance which was so urgently needed. Time after time notification of a vessel, helpless and at the mercy of the waves, was sent through the air to shore, and succour extended before the coastguards had heard or seen the rockets which were being fired from the endangered craft. Moreover, the lifeboatmen were saved many an abortive journey. A ship drifting towards the sands would fire her rockets for help. Yet at the critical moment, possibly owing to advice extended from the lightship by means of the gun, she would escape the menace. But for the wireless the lifeboatmen, in answer to the rockets, would have put out and have been surprised, upon reaching the danger spot, to have found no signs of a ship, or only to learn that she had reached safety.

The utility of this installation drew the attention of Lloyd's to wireless telegraphy, and they decided to install the system in their signal stations for the purpose of sending intelligence concerning passing ships from point to point. The first maritime connection of this description was that between Ballycastle and Rathlin Island, that wild corner of the North of Ireland.

The maintained successes which Marconi's invention had achieved naturally attracted the attention of the whole world. What three years before had been regarded merely as an interesting laboratory experiment was now accepted as an indispensable commercial factor. While Marconi's triumphs tempted many other inventors and toilers to enter the same field, certain Governments were anxious to acquire his system for their especial purposes. Among these was France, but they were anxious to ascertain from a conclusive demonstration of the system whether he could send wireless messages across the Channel. Marconi accepted the challenge, and the latter part of the year 1898 and the opening months of 1899 were devoted to the completion of the respective installations upon either side of the Channel. A mast was erected upon the Town Hall at Dover, while another lofty aerial was set up at Wimereux, near Boulogne. The distance to be spanned through the air was thirty-two miles. Incidentally it may be mentioned the French demonstration represented



PICTURE DIAGRAM SHOWING HOW WIRELESS COMMUNICATION IS KEPT UP BETWEEN A SHIP AND A SHORE STATION

An engine of 200 horse-power in the shore station drives a dynamo which supplies the electrical power to send the Hertzian waves over thousands of miles of sea, and the aerials on the ship receive the message, which is transmitted to the instrument in the Wireless cabin.

the greatest distance over which wireless had been attempted up to this time.

On Monday, March 27th, 1899, all preparations were completed, and the representatives of the French Government gathered at the Wimereux station. The actual operations were carried out by Signor Marconi himself in co-operation with his chief engineer, Mr. Jameson Davis. At five o'clock everything was ready for the sending of the first wireless message across the Channel. The French engineers and scientists gathered round the instrument, the Morse key of which was held by Signor Marconi. One and all were on the tiptoe of expectancy.

Signor Marconi depressed the key giving the Morse code of the letter "V," which signified the call. Slowly and deliberately he sent the first brief message, in which he informed Dover that he was using a two-centimetre spark. Then the letter V was again repeated three times, signifying the end of the message.

Intense silence reigned in the room, the ears of one and all being strained to the utmost to catch the faintest click in the receiver. The tension lasted for a few moments. Then came a loud ticking of dot and dash. The roll of paper on the tape-wheel spun round, and as it was scanned the dots and dashes of the Morse code were observed to resolve themselves into the Roman characters forming the words:

"Your message is perfect. Same here. Two centimetres."

And the apparently impossible was accomplished. The Channel was bridged by wireless.

The unfaltering manner in which the message came through impressed the assembly. The profound silence, broken only by the ticking of the instruments, gave place to animated conversation and hearty congratulations. Message after message was thrown into the air to be caught at Dover, and every time, without the slightest mistake or hesitation, came the desired reply. For days the French representatives tested the apparatus and travelled to and fro across the Channel investigating every detail at both stations.

The wireless spanning of the Channel may be said to have brought the first and experimental era of telegraphing without wires to a close. Its commercial utilisation and success were assured. Signor Marconi had succeeded in sending and receiving signals which were perfectly intelligible to those conversant with the code from 100 yards to 32 miles, and that within the short span of four years! Six months later, in September, Signor Marconi was honoured by a visit from the British Association, when Professor Fleming, who has always manifested a keen interest in, and admiration for, Marconi's work in this realm, explained and demonstrated the apparatus to his scientific colleagues. On this occasion messages were exchanged between a small station set up in the lecture hall and the Goodwins Lightship and Wimereux respectively. While the signalling was somewhat slow, owing to the sluggishness of the Morse code, the scientific gathering remarked upon its reliability in the new field of application, and agreed that the arrangements incorporated by the inventor in his system were of remarkable simplicity.

Indeed, the year 1899 was one of considerable historic moment to the Italian inventor. The British

Navy were conducting experiments with the system upon an extensive and comprehensive scale. It was pressed into service to report the progress of the race between the *Columbia* and *Shamrock* for the America Cup, in connection with which over 4,000 words were transmitted within less than five hours, spread over four days; while the United States Government also fitted two warships with instruments to satisfy themselves upon its utilisation for naval operations.

This year also witnessed the birth of what has now become recognised as a tradition. Mr. Marconi was returning to this country, after the American yacht race, on board the liner *St. Paul.* The South African War was in progress, and the passengers on board, having been kept in ignorance of the progress of the campaign for approximately one week, suggested to Mr. Marconi that, as the vessel ran up Channel he should get into touch with the Needles station, learn the latest news, and allow the same to be printed on board. Mr. Marconi heartily approved of the novel suggestion, hurriedly rigged up an installation which he had on board, and succeeded in getting into touch with the Needles from a distance of seventy miles. The fragments of intelligence which were received were printed in a small paper which was christened the *Trans-Atlantic Times*. The run on this paper was probably without precedent in the annals of journalism. The limited edition was sold out immediately, and the passengers were posted up with the latest news of the war some hours before they reached Southampton. Thus the wireless newspaper at sea was inaugurated, an institution which to-day meets with widespread appreciation among travellers upon the seven seas.

Incidentally another development was introduced upon this voyage—the maintenance of telegraphic communication between passengers and the mainland. Several travellers seized the opportunity to send telegrams to friends and relatives from mid-Channel announcing their arrival. Apart from the novelty of this occasion the fact was revealed that a highly remunerative business might be founded upon this traffic, and in this connection anticipations were not denied, as the volume of such business to-day testifies very conclusively.

This establishment of communication between a liner travelling at 20 knots and the shore, although carried out upon the spur of the moment and in an unpretentious manner, was not without its tangible results. A German steamship company saw its advantages and secured the installation of a wireless set upon its fastest Atlantic greyhound, and two stations ashore. This was the first ship to be equipped with wireless for the assistance of navigation and the convenience of the passengers, and it proved exceedingly popular, 565 messages being handled within less than six months. The next move, so far as marine operations were concerned, was the equipment of the packet boats running between Dover and Ostend.

Long-distance wireless having been proved to be feasible beyond the shadow of a doubt, Mr. Marconi now devoted his attention to the fulfilment of his most ambitious dream—the establishment of etheric communication between Great Britain and North

America. To this end the erection of two powerful stations was taken in hand, the one at Poldhu, in Cornwall, and the other at Cape Cod, Massachusetts, U.S.A. At each station elaborate and lofty masts of steelwork were run up to carry the aerial.

Up to this time Marconi had suffered but little delay and interruption from outside causes during his experiments, but this latest and greatest enterprise appeared to be dogged with ill-luck. The station at Poldhu was completed sufficiently to enable experiments in transmitting across the Atlantic to be commenced, but on September 18th, 1901, they were brought to a summary, though temporary, cessation by a severe storm which destroyed the masts. Two months' hard work, however, sufficed to restore them sufficiently to enable the task to be resumed. Then an accident befell the Cape Cod station, the masts of which were so damaged as to indicate the lapse of many months before they could be repaired.

This second accident was exasperating, but sooner than delay further experiments he set out to Glace Bay, Newfoundland, where he decided to use a temporary station to ascertain whether or not the arrangements which were being laid down at Poldhu were being carried out upon the correct lines. Large kites, to which receivers were attached, were sent aloft, and to the wire establishing communication with the ground a telephone receiver was connected, the signals which were thus received being announced by a series of clicks.

An arrangement had been made with the operators at Poldhu to the effect that after December 11th, 1901, a succession of "S's" followed by a short message should be sent out during certain hours every day. The next day the signals thus dispatched from Cornwall were distinctly received at Glace Bay and at the pre-arranged times, thus indisputably proving that the Atlantic could be bridged by wireless, and that the transatlantic expansion of the development was entirely dependent upon the suitability of the apparatus.

In the meantime the wireless equipment of mercantile vessels, owing to the success of the installation upon the German liner, progressed rapidly. The first British liner to be provided with this facility was the s.s. *Lake Champlain*, of the Beaver Line, in May, 1901. Other shipping companies speedily emulated the example, and the Cunard liner *Campania* was the first to be fitted with wireless capable of receiving messages up to 1,000 miles. These steamships proved invaluable in connection with the experiments at Poldhu, and recalled the days, some five years before, when the tug was requisitioned to extend wireless across the Solent. Slowly but surely the distance at which the invisible waves could be trapped and deciphered into messages increased until, in February, 1902, the liner *Philadelphia* remained in communication with Cornwall over 1,551 miles, while she received the "S's" up to 2,099 miles.

These achievements were distinctly encouraging. So much so, that Mr. Marconi began the construction of a high-powered station at Cape Breton to complete further tests, which work was appreciably facilitated by the liberal grant of £16,000 from the Canadian Government. While this station was under erection, experiments were continued with the cruiser

Carlo Alberto, which the Italian Government placed at the disposal of its distinguished son. From this vessel, in which Mr. Marconi sailed for Canada in October, 1902, signals were exchanged with the Cornish station throughout the voyage across the Atlantic up to 2,300 miles. A few weeks later Poldhu and Glace Bay were in wireless connection, and transatlantic wireless telegraphy became an established fact. During the spring of 1903 a regular service of American news messages was transmitted by wireless from Glace Bay by arrangement with the *Times*, and success was achieved, although it had to be suspended a little later owing to a breakdown at the Canadian station. Six months later another notable record was established, the Cunarder *Lucania* being in news communication with Poldhu during the entire crossing from New York to Liverpool.

While the Poldhu station proved satisfactory it was subsequently decided to construct a new and more powerful station for transatlantic wireless upon the extreme western coast of Ireland. Clifden was selected as the most suitable site, and here the most modern and complete installation was carried out. To-day, while Poldhu is in operation, it is virtually reserved for the handling of messages between ship and shore, while that at Clifden is reserved for commercial and other messages between Great Britain and America.

During the past few years wireless telegraphy has made enormous advances in all parts of the world. The Germans, no doubt somewhat piqued at Marconi's success, developed an individual system known as the "Telefunken," the joint invention of Professor Slaby and Count Arco. But it was not until the first named had seen Marconi's system at work that he succeeded in achieving any success with his own idea. As he acknowledged several years ago, Marconi succeeded where he failed. Yet this fact has not deterred the Germans from attempting to wrest the credit of the invention from the Italian electrical engineer. There has been pronounced jealous rivalry between the two systems, the outcome of which at one time threatened to prejudice wireless in the eyes of the public. The German company grew jealous of the success of its Italo-British rival, especially in connection with the equipment of vessels of the mercantile marine, and this feeling was undoubtedly accentuated because certain German lines embraced the Marconi system in preference to that evolved by native experimenters.

The outcome of this antagonism was somewhat disastrous to the development of wireless telegraphy as a whole. The German company, in the determination to compel the wider adoption of its system, refused to accept messages dispatched from ships equipped with the Marconi instruments, and in due course the Marconi company retaliated in a similar strain. This impossible situation was overcome eventually by the ruling of the Radio Telegraphic Convention refusing to acknowledge such distinctions, and compelling one system to exchange with the other. By this action universal wireless became possible. At the same time, however, the feeling of rivalry between the Anglo-Italian and German interests has never been subjugated; it is still as acute as ever, but covertly.

The value of wireless telegraphy was first brought home to the general public when a terrible disaster was narrowly averted on the broad Atlantic. Two liners came into collision, and one was damaged so severely that she commenced to founder. The operator upon the stricken ship at once frantically flung the emergency call, comprising the repetition of the letters "S.O.S.," into space. The signals were caught by receivers upon all other vessels within range, and instantly there was a hurried rush of ships from all points of the compass to the scene of the accident. Thanks to wireless, vessels came up in rapid succession, the result being that a terrible nerve-racking wreck, with all its horrors and appalling death-roll, was averted. Time after time a disaster at sea has been avoided or minimised by wireless, and it is safe to assert that the Marconi invention has contributed to the safety of thousands of lives, many of which have only been snatched from certain death in the nick of time.

The incalculable utility and value of wireless in connection with maritime traffic did not fail to exercise its effect upon the nations of the world. There were discussions and conversations between the representatives of Governments, and at last laws were passed by the foremost Powers compelling the installation of wireless telegraphic apparatus upon passenger-carrying ships. While these laws are drawn up to meet the direct requirements of the respective nations, they are fundamentally the same, so that arbitrariness is avoided. To-day there is not a liner sailing the seas which has not its wireless on board, so that in time of emergency the passengers and crew may be given a fighting chance for their lives.

So far as commercial developments are concerned, although wireless has not superseded submarine cables and overhead or underground wires, it is supplementing the latter to a very pronounced degree. Then, again, it has enabled telegraphic communication to be carried through countries where the ordinary systems are not to be found for the simple reason that they never could hope to pay their way. The barren territories surrounding the Poles are even being linked up with the humming commercial and industrial centres of the globe. Thus we have a wireless station in Macquarieland, where a few hundred enterprising and daring pioneers strive to make existence profitable, although it is on the fringe of the silent continent enveloping the South Pole. Wireless is serving as a connecting link over the vast distances separating the communities who are making good in far-away Alaska. Wireless has forged a link of conversation through the wildest and undeveloped parts of the South American continent, and of the darkest reaches of territory in Africa. Formerly the railway or the telegraph wire was considered to be the herald of civilisation and the open sesame to a new country; but to-day it is wireless which is fulfilling this rôle.

Nowadays it is virtually impossible to particularise all the applications of etheric communication. By this means the aviator keeps the commander of an army beneath him posted up with the movements of the enemy. Warships talk to one another by its aid. From the Eiffel Tower the time is dispatched every noon throughout the world. The most distant stations receive the signal within the fraction of a second, and as it is Greenwich time which is flashed through space the recipient can correct his own timepiece after making due allowance for his geographical position east or west of Greenwich. Longitude is now determined and verified by the aid of wireless, whereas formerly it had to be carried out by chronometers, and was not only a prolonged but a tedious operation. To-day it can be ascertained within a matter of hours. Regular wireless services for the transmission of commercial and private business are maintained throughout the world, and such transmission is cheaper than cable communications. Recently it has been pressed into service in connection with the operation of railways in the United States. The trains carry a small cabin reserved for the operator and his instruments, and he can speak with, and receive orders from, various stations while making sixty miles or more per hour along the steel highway as easily as conversation through the ether can be carried on between stationary points.

The latest development in connection with Marconi's epoch-marking invention is in connection with talking through space—that is, telephoning through the air without wires. This phase of the development is described in the chapter devoted to the story of the telephone. But the most wonderful feature of the romance of etheric communication is that it has been brought to its present stage of high perfection and universal use within the short span of two decades. Twenty years ago Marconi was able to throw signals through space over a distance of 1½ miles; to-day, by means of the telegraphic code, he can fling messages through the air right round the earth, or approximately 25,000 miles.

CHAPTER II

The Discovery of Cheap Steel

WHAT discovery has played the most prominent part in the progress of the world, and has been the means of creating the greatest number of millionaires? At first sight this question may appear to be impossible to answer in a conclusive manner, inasmuch as every invention has played its particular part in the amassing of individual wealth. But a little reflection will serve to prove that the world to-day virtually depends for its existence upon one article, the cheap production of which has materially influenced every other invention and industry, and has proved the means whereby nearly every creative genius has earned the fruits which are due to him for his manifestation of endeavour.

This is the age of steel. It plays a vital part in the welfare and advance of the nations, whether it be devoted to the blessings of peace or the curses of war. Its influence is experienced in every branch of manufacture and industry in one form or another. Yet it was only sixty years ago that the steel age was truly ushered in, and that through the activity of one diligent toiler. Although steel was known before this investigator announced his process through the medium of the Patent Office towards the end of 1855, it was an expensive luxury, and was exclusively dependent upon hand-labour, which is notoriously slow and expensive, especially when regarded by our modern methods of comparison.

The foregoing date has since proved to be one of the most prominent milestones in the history of industry and commerce—indeed, of the world itself. But it was not only an Industrial Emancipation Day from the fact that it released the iron and steel producers from the yoke of hand-labour. It contributed to the cheaper manufacture of every other article which is dependent more or less upon this commodity, because the time occupied in the manufacture of steel was reduced from a day and a half to twenty minutes.

Every country between the two poles can point to its coterie of steel magnates. Yet the foundations of the fortunes of all of these men were laid by a British inventor. True, the latter amassed a fortune which he considered an adequate reward for what he had accomplished, but it was as a drop in the bucket when compared with that acquired by many who followed him and benefited from his genius.

Although the cheap process for the production of steel did not meet with publicity until 1855, the inventor, Mr.—afterwards Sir—Henry Bessemer, then forty-two years of age, had already given several striking illustrations of his creative ability. At twenty he should have netted a huge fortune through saving the Government a round £100,000 a year.

But governments ever maintain a lukewarm, hostile, or niggardly attitude towards inventors, and young Bessemer was no exception to the rule. He had the bitter mortification of seeing the fruits of his labours appreciated and appropriated, but without a pennyworth of material recognition to himself. Even a lucrative appointment which had been promised to him as a reward for his ingenuity failed to materialise. It was suddenly cancelled.

As may be supposed, the trusting village lad cherished a decidedly harsh opinion of the world in general, and a deep disgust at the treatment which had been meted out to him, but indirectly it proved the most valuable lesson he had ever learned. He bought experience at an early age. Ever after he trod with extreme wariness during the critical periods when it became necessary to submit creative genius to the stern test of practical application.

Bessemer displayed many illustrations of his remarkable inventive ability before he ever turned a thought to the study which caused his name to vibrate through the world. Unfortunately, he was not liberally endowed with the sinews of war, and so had to depend upon the fertility of his creative faculty to earn the wherewithal to continue his inventive pursuits. His attention was drawn towards gold-printing, in which bronze powder is used. He noticed that the work was costly, and to him the reason seemed decidedly obscure. The material then in use was a German product, and he instantly endeavoured to ascertain if he could not beat the Teuton at his own game. After considerable experiment he succeeded, and to such a degree that he could market his commodity at about a thirtieth of the price demanded by the German producers.

This discovery was not patented : it was worked secretly. Once the commodity had secured a firm hold upon the market he decided to lay down an extensive automatic plant for its production. He established a factory in St. Pancras, and, assisted by one or two relations, he installed the machines for the manufacture of the substance. Bessemer, remembering his former experience with a valuable invention, spared no effort to prevent any details of this secret, or of its special machinery, leaking out. The latter was even built secretly, the cautious inventor ordering certain parts from one firm, others from another, and so on, while assembling was carried out by himself and his colleagues.

An interesting sidelight upon Bessemer's goodheartedness, which, by the way, was frequently manifested during his later years, was revealed in connection with this industry. When his attention became centred upon the steel invention and its financial success was assured, his relatives continued the bronze factory for him. One by one they died, until at last only two remained, and they had grown old in the service. Bessemer forthwith rewarded them for their steadfast assistance and loyalty to him by presenting them with the business, lock, stock, and barrel, including the secret of the process. During its early days, however, the bronze-powder factory was absolutely indispensable to him, because it furnished him with the money whereby he was able to carry out his costly experiments in connection with the production of steel.

Bessemer's thoughts were attracted to this new field from the search which was being made by the French Emperor Napoleon III. for a material from which improved artillery might be built. The problem fascinated him, and thereupon he concentrated his energies entirely upon its solution. At that time all steel was produced by what is known as the " converting " method, and it was an extremely prolonged operation, while naturally the product was expensive, ranging up to £70 per ton. Hand-labour entered very extensively into the manufacture of the metal, and the output was relatively small.

Bessemer, animated by the French Emperor's interest in the subject, sought to improve the commercial cast iron then in vogue by adding thereto a small quantity of steel. He prepared some of this metal from which he cast a small model gun. He went to France and exhibited it to the Emperor Napoleon III. It was examined, and the metal being observed to be harder than that from which cannon were then being made, he was given permission to erect a furnace of sufficient size to enable a 10-ton gun to be cast at the Government works at Ruelle.

He returned to England to complete the preliminary preparations. Suddenly, as he was turning the subject over in his mind, he conceived an idea for making an improved wrought iron upon an extensive scale by the simple process of driving a current of air through the molten mass. In one respect this inspiration was to be regretted ; it turned him from the original line of thought for ever. Had he continued his first line of experiment it is certain that he would have anticipated the Martins-Siemens open-hearth process, which has now a greater vogue than the Bessemer method owing to the greater proportion of ores being more suited to the former than to the latter treatment.

Naturally, the first experiments were carried out

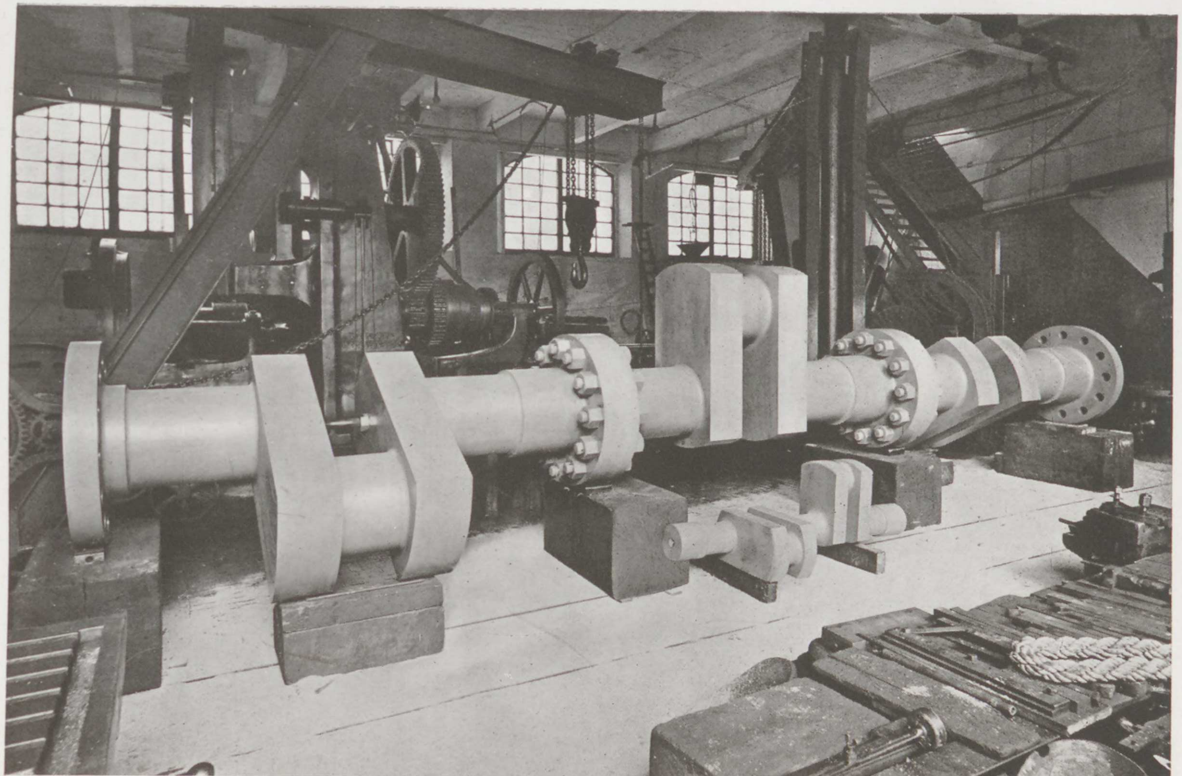


Photo by courtesy of Messrs. Bessemer & Co., Ltd.

A TRIUMPH OF BESSEMER STEEL-WORK

The large crank-shaft, made for a steel-roll mill, weighs 30 tons. In front of it is the crank-axle of an English railway engine, which ran continuously during 35 years, with a mileage of 1,252,340 miles to its credit. And no signs of a crack!

with primitive facilities to determine the substance of his idea. Air was injected into a crucible of molten iron. But the experiment was a startling success, because the investigator discovered that he had transformed cast iron into a far tougher metal within half an hour, and by a very simple agency.

This preliminary investigation proving so promising, he then prosecuted further researches upon a more comprehensive scale within the sanctuary of his bronze-powder works, where he was secure from interruption and prying eyes. Successive converters were built, each embodying some improvement upon its predecessor, until finally he built a stationary vessel, some 3 feet in diameter and approximately the same in height, out of firebrick. This "converter," as it was described, was enclosed in a box known as the blast-box, from which pipes or tuyères, as they are technically called, entered the sides of the converter near the bottom. From the blast-box a feed-pipe extended to the blowing engine, whence the blast of air was supplied as required. Near the top of the converter was a hole to act as a vent for the flame produced during the blowing operation.

When Bessemer set his first converter going he was completely astonished at the commotion which took place in the molten iron. The oxidation of the carbon and the silicon, he related, presented "a miniature volcano in a state of violent eruption. All this was a veritable revelation to me, as I had in no way anticipated such violent results."

Fortune played a certain part in Bessemer's investigations. At that time but little was known concerning the chemistry of iron, and nothing about the permission to use the process in their respective shops for the sum of £10,000 apiece. The inventor sold outright for the lump sum; that is to say, there were no further payments to be made in the form of royalties, which meant that each firm had secured the right to exploit the patent during its term of fourteen years.

Bessemer received his payments in hard cash, and within a month found himself the richer by some £27,000. The money was necessary to him. The experiments had proved costly and had made great inroads upon his slender income, which came mainly from the exploitation of his bronze powder. Now he was in a position to prosecute further investigations and without fear of any financial worry.

However, he was destined to receive a rude shock. The firms who had acquired the rights to use the process laid down converters in their works with all speed, and within a short time were busily engaged in converting iron into steel. But, to their dismay and disgust, they could not produce a pound of metal which approached that exhibited by Bessemer. Indeed, every effort proved a dismal failure. This ghastly sequel came as a staggering surprise to everyone, including Bessemer himself, who was totally at a loss to explain the reason for the failure. Now, the very ironworkers who a few months previous had been wildly enthusiastic over the discovery, and who had fallen over one another to acquire licences to work it, turned completely round. They vehemently branded Bessemer as a charlatan, rogue, scoundrel, trickster, thief, and whatever other opprobrious term they could call to mind. They stormed and threatened, and demanded their money back.

The storm startled Bessemer, as may be imagined. But he was convinced that an explanation could be found for the unexpected development. Samples of the worthless, brittle, and rotten steel were sent to him from each of the outraged ironworkers. Bessemer repeated his experiment with the Blaenavon pig iron, and the success of his first results was repeated. Then he ascertained what brand of pig iron each of the indignant ironworkers was using. He found that each firm utilised its peculiar brand. From this it was apparent that steel could be made from one brand of pig iron, but not from others. Why? That was the crucial problem, and Bessemer set out to solve it. Undoubtedly the chemical composition of the pig iron had a great deal to do with the matter.

Bessemer, being ignorant of chemistry, as previously narrated, searched high and low for a chemist capable of conducting a series of experiments which he had in mind. At last he succeeded in discovering a man who expressed the opinion that he thought he could work out ways and means of determining the composition of the different samples which had been sent to Bessemer. He went ahead, and after considerable investigation returned with his results.

The work of the chemist surprised but pleased Bessemer. His innermost thoughts and non-technical reasons for the failure were fully vindicated. The good steel, such as he had made, was low in phosphorus and sulphur, but the bad samples were rich in these two ingredients. Bessemer digested these chemical analyses, but kept them rigidly to himself. The work of the chemist had set him thinking once again. He embarked upon a series of further experiments.

Simultaneously he explained his dilemma to one or two intimate friends. The outraged ironworkers would have to be placated by hook or by crook, and he could think of no more satisfactory manner to achieve such an end and thereby rehabilitate himself in their estimation than by repurchasing the licences which he had previously disposed to them. Incidentally, he entertained his personal opinion that he had sold his rights at too low a price. His invention was far more valuable than it had first appeared to him.

The repurchase of the licences thus became his first objective. But he was in need of some assistance to consummate this end. Would his friends help him? They agreed, and thereupon Bessemer, with apparent regret, approached the dissatisfied ironworkers and offered to relieve them of their apparently bad bargains. But it did not prove so simple a task to buy back these licences as he had imagined. One firm point-blank refused to part with the rights for less than £20,000, although only £10,000 had been spent upon their acquisition. However, at last, Bessemer, after considerable difficulty, achieved his purpose. The five licences were re-acquired, and he was in sole and undisputed possession of his invention.

Meanwhile, Bessemer had been engaged in the construction of another experimental plant with which to carry out further trials upon a more extensive scale. He ascertained that the raw material which he had first employed was made from West Cumberland ore. As it was low in phosphorus, the indispensable condition for his purpose, he arranged for a further supply of pig iron made from the West Cumberland ore. The consignment arrived at the small works which he had established in Sheffield and was submitted to his treatment. But to his disgust he discovered that the resultant steel was nothing like that which he had first obtained, and was as rotten, brittle, and useless as that which had been made by the dissatisfied licencees.

This surprise was a poser, but confident that some explanation was forthcoming, he passed the steel on to his chemist. The analysis came to hand and showed that the steel was rich in phosphorus. Now the raw ore was low in phosphorus, but the steel was rich in this chemical. How had this surplus of the bad element entered into the pig iron? To him it was an inexplicable riddle, but he decided to attack it and to probe it to the bottom. He hastened to West Cumberland and sought out the manager of the ironworks at which the pig iron had been prepared, his object being to follow the process of producing the pig from the raw ore, which he knew full well complied with his requirements. While passing through the works the observing Bessemer detected a pile of dingy-looking rock which aroused his curiosity. He examined it closely, and then, turning to the manager, inquired blandly:

"What is this?"

"The flux we use," was the retort.

"Yes, but what *is* it?"

"Oh, puddle furnace cinder!"

Bessemer could not curb a low ejaculatory whistle. He had stumbled upon the reason for the exceptional proportion of phosphorus in the pig from which he was attempting to make his steel, because he knew only too well that this cinder must possess a high percentage of this constituent. But, concealing his satisfaction, he turned to the manager again inquiringly.

"Why do you use it?"

"To make the furnace work smoothly and the iron fluid," came the immediate response.

"Oh, well, if you will make the pig iron which I desire from straight ore, and without using any puddle cinder, I'll give you an order right away."

The manager assented, and Bessemer, his peace of mind completely restored by what he had ascertained from his personal investigation, returned home to await the first consignment of the raw material prepared to his instructions. The latter was made, and the ironworks, not knowing how to describe the metal upon the invoice, since it was not their particular brand, entered it up after the name of the customer. It was invoiced as "Bessemer iron." Strange to say, this name has remained ever since, and to this day "Bessemer iron" is generally known throughout the world as pig iron having a very low phosphorus content.

Upon receiving a further supply of this raw material Bessemer repeated his experiment, and, as he had anticipated, the resultant steel was every whit as good and possessed of the self-same characteristics as what he had first produced and had exhibited at Cheltenham from "Blaenavon" pig. Having subjugated the primary initial difficulty in such a complete manner it was now all plain sailing. Improvements were made from time to time, necessitating additional patents, the culmination of which was the production of a perfect steel.

He established his works at Sheffield in 1858, being assisted in this enterprise by Mr. W. D. Allen, whose association with Bessemer was lifelong, Mr. R. Longsden, a former partner in London, and Messrs. Galloway, of Manchester. Under the quadruple partnership thus formed the works of Henry Bessemer and Co. were established and are still in operation.

For a time steel appeared to be a drug upon the market. Commerce was somewhat slow to recognise the virtues of the new metal. Possibly the failure attending the results of the first commercial exploitation of the invention contributed to this apathy.

Yet there was every inducement to purchase the converted iron. Steel produced by the manual methods in vogue was costing from £60 to £70 per ton, whereas Bessemer was marketing his product at from £40 to £50 per ton. Notwithstanding the pronounced difference in price but little trade was done during the first two years of the firm's existence.

Suddenly commerce appeared to realise, in an instant, the advantages of the stronger and tougher metal and its many feasible applications. The competitive firms in Sheffield who had previously derided the process became alarmed, inasmuch as they were being undersold, and were in danger of having their steel trade taken away from them.

Bessemer was once again brought into conflict with the trade. The firms who had bought the licences originally at Cheltenham, and had subsequently parted with them again to the inventor, now approached him, money in hand, to regain permission to employ the process in their shops. But to their surprise they met with a curt refusal to entertain such offers. Bessemer explained that he had ascerthe air greedily devours the carbon and other chemicals present, removing them in the form of oxides. Only one chemical constituent refuses to be ejected summarily in this manner. That is the phosphorus.

A Bessemer converter in full blast presents an inspiring spectacle. When the air jet is brought into action a thrilling pyrotechnic display is precipitated. A huge volume of flame shoots out of the mouth of the vessel, accompanied by a coruscating mad shower of sparks—the silicon—which fly in all directions. The turmoil increases as the air blast settles down to its work, and continues until the silicon, carbon, and other elements have been removed, when the spark shower and the tongue of flame diminish, the fiery liquid within the converter ultimately reverting to a condition of comparative quiescence.

After settling down to manufacture, Bessemer discovered that in order to render the steel malleable for rolling or hammering in its heated condition, a certain proportion of carburet of manganese was necessary. But his freedom to add this element to the molten steel was vigorously challenged as the discovery of another investigator, Robert Mushet, and had been duly patented. This constituted a thorn in the side of the steel inventor, which was aggravated by one of the licencees to whom Bessemer had originally sold the right to exploit his invention, and which he had bought back. This firm had striven to compel Bessemer to re-sell the shop rights to them, but, as already related, he refused to entertain any offers except upon the royalty basis. The firm in question acquired an interest in Mushet's patent, and then, realising that Bessemer could do little or nothing without the carburet of manganese, attempted to mulct the steel inventor in royalties for permission to use Mushet's patent. It proved a powerful weapon with which to assail Bessemer, but the latter maintained that Mushet's patent had been anticipated. The situation, however, was responsible for the creation of pronounced animosity between Bessemer and Mushet.

Yet Fortune, which had waited upon Bessemer, did not desert him. Mushet learned, to his cost, as Bessemer had learned years before, that creative genius and commercial acumen must go hand in hand. Mushet was not a business man. He left the handling of his patent to a partner, who does not appear to have been very astute. Either through negligence or forgetfulness, this partner omitted to pay the annual fee for the maintenance of Mushet's patent. The result was that it lapsed, became public property, and could be used by anybody and everybody, including Bessemer.

The steel inventor now found himself in a powerful position, and released from the trammels of the hostile firm which had been assailing his employment of what they claimed to be Mushet's discovery. But while the summary lapse of a rival contentious patent assisted Bessemer, it ruined his rival. Mushet, who had been induced to expect a large nest-egg out of his discovery, was forced to penury, and would even have been compelled to struggle hard for the bare necessaries of life but for Bessemer's generosity.

The steel inventor subsequently learned that Mushet had not contributed to the ill-feeling which had arisen between the two men. One afternoon Bessemer was in his private office when there came a knock at the door. A clerk answered, to find a young woman, neatly though poorly clad, and evidently in sore distress. She wished to see Mr. Bessemer. Her voice was pleading, and her mission apparently so sincere that she was ushered into Bessemer's presence.

Here she made herself known as the daughter of Mr. Mushet, and went on to explain that, having heard that Mr. Bessemer was a kind-hearted man, she had decided, upon her own free will and unknown to her father, to seek out the steel inventor and to explain the dire straits to which they had been reduced. Her father and his family were so poor that they scarcely knew how to continue the struggle for existence. Gathering confidence as she related her sad story, the young woman stated that she had heard that Mr. Bessemer was making a lot of money out of her father's invention, the fruits of which he had lost through no fault of his own, and she had come that day in the hope that Mr. Bessemer might be able to see his way to assist them.

The steel inventor listened in silence to the sad story. When his visitor had completed the narrative a few diplomatic questions convinced him that the woman's story was indeed true. There and then he comforted the daughter by declaring his intention to see that Mushet should pass the evening of his days in comfort. The woman brightened up and returned home confident that Bessemer would adhere to his word. He did so, settling an annuity of £300 upon his former and now unfortunate rival.

Bessemer's works in Sheffield grew and flourished in an amazing manner. Here flocked all the iron-makers not only of Britain, but of other parts of the world. Even when the business was firmly established and its resources were taxed to the utmost to keep pace with the orders which poured in, Bessemer was still busy with his experiments. The great idea had been brought to a stage of perfection, but details in the apparatus employed could always be improved. The stationary converter which Bessemer first contrived was finally superseded by the tipping vessel. This final converter was considered so simple and efficient that it has virtually never been altered, except in a few minor details, and in accordance with the accumulation of knowledge and experience.

After the first two years of trying difficulty and indifferent trade, the firm enjoyed a remarkable spell of prosperity for twelve years. During this period the four partners who constituted the firm and who had financed the enterprise received their original capital back no fewer than fifty-seven times, representing dividends, if such they may be described, equal to nearly 500 per cent. per annum. At the end of fourteen years the quadruple partnership was dissolved, the business being converted into a private limited company, the purchase price being equivalent to twenty-four times the original sum of money invested in the undertaking. Bessemer amassed a huge fortune, his income in 1866, eight years after commencing operations, and when the boom in Bessemer steel was at its height, averaging in round figures £500,000 per annum.

The life of the patents came to an end in 1870, and concurrently with their expiration Bessemer, at the age of sixty, retired, a millionaire, from all active participation in the steel industry.

The influence which Bessemer's invention exercised upon the prosperity of these islands may be gathered from the fact that in 1855–6, when Bessemer lodged his first patents, only about 50,000 tons of steel per year were being produced by this country. In 1898, the year in which he died, the output had risen to 4,665,986 tons, of which 1,759,386 tons were produced by his process. During the year 1915 the United Kingdom produced 8,350,944 tons of steel, of which 1,301,224 tons were Bessemer, the balance of 7,049,720 tons being the product of the open-hearth process, which has superseded the Bessemer method of steel production to a pronounced degree.

There is one curious incident in connection with the story of the invention which ushered in the steel age that is worth recording. At the age of sixty-eight Bessemer was knighted. But this honour was not conferred as a slender recognition of the far-reaching influence which his creative genius had exerted, but was bestowed for having saved the Government £100,000 a year by the invention which he evolved when an unknown lad of twenty! This was the only reward he ever received for this achievement, and that forty-six years after it had been adopted! Even this acknowledgment of his services to the State would never have been extended had not the inventor, during the evening of his life, rudely stirred the memories of the powers that be by a recapitulation of forgotten and broken promises.

CHAPTER III

The Story of Coal-Gas

SOMETHING like two hundred years ago the residents of the northern town of Warrington were thrown into wild excitement and a state of frenzied alarm.

The cause was an old, abandoned, and almost forgotten well in the neighbourhood. As wells, when permitted to fall into disuse, will do, this particular hole, which had been sunk for water, became charged with a noxious gas. But it was not the usual gas which is found under such conditions. The townsfolk were positive upon this point, but they could offer no reason as to why it should not be carbonic acid gas which gathers in wells. They scratched their heads and discussed the subject animatedly, but they could not offer any explanation of the mystery.

News of this peculiar gas became noised throughout the countryside, to come, some years later, to the ears of a well-known clergyman. The reports interested him, because, being a man of science, the apparently inexplicable exercised a strange fascination. Accordingly, the Rev. Dr. John Clayton decided to visit the well and to probe the mystery upon the spot. His investigations aroused considerable interest among the unsophisticated countryfolk, who followed his movements with a strange, almost breathless, excitement. When he withdrew his tinder-box, and lit a rush candle in broad daylight, their speculation as to his intentions rose to fever-pitch. But the reverend doctor had made a shrewd surmise, and he was going to put his deduction to the test. He approached the well, and applying the lighted candle to its mouth, had his expectations realised to the full, though it brought dismay to the surrounding onlookers. There was a loud report—a sheet of flame burst from the well.

The countryfolk flew in terror to their homes, shouting excitedly as they did so, and in awestricken tones told those whom they passed about the burning well, which they declared was charged with "spirit" gas. From their frantic alarm it is only possible to surmise that the good people of Warrington firmly believed the fire to come from the nether regions. The reverend doctor was the only man amongst them who remained calm. Recognising the terror he had unwittingly caused by his simple test, he restored the placidity of the residents in the vicinity before he returned to his home. But his experiment was long the topic of conversation in the north.

The phenomenon set the reverend gentleman thinking deeply. To him it was not extraordinary, and he immediately embarked upon a number of experiments to determine whether he could not reproduce the effect in his laboratory, having discovered the character of the gas and its obvious origin. He built a tiny furnace, which was completely closed except for a small hole. This he charged with soft coal and lit a fire beneath it. As the coal was cooked or, as we call it to-day, distilled or carbonised, steam came out of the aperture. This was water being driven off by evaporation. Then a stream of pungent, thick black fluid, resembling oil, oozed lazily from the orifice. In a short while this ceased. Then he applied a light to the opening, and, as he had confidently expected, a tongue of flame burst forth and continued to burn for a few seconds. He had produced " spirit " gas, such as was found in the abandoned well, in his laboratory.

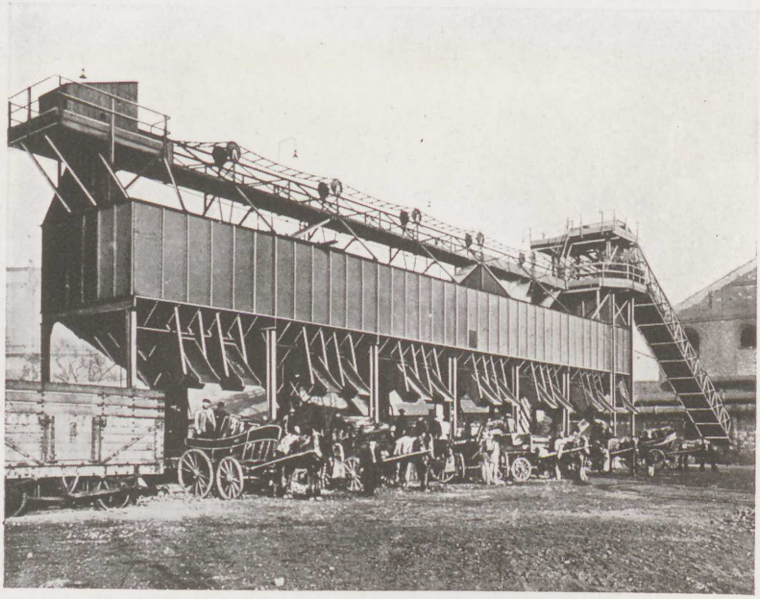
As a result of this discovery Dr. Clayton devised a new means of entertaining his friends. Instead of burning the gas as it came from the little furnace, he led it through a small length of pipe into bladders which became inflated therewith. Upon a bladder becoming fully charged its mouth was tied tightly, and in this manner the gas was stored. When his friends visited him he would take one of these bladders, puncture it with a needle, and, holding it in his hand, would apply a light to the hole. The gas instantly caught fire, and continued burning until the contents of the bladder had been consumed. Watching the " spirit " gas burn itself out in this manner constituted a source of infinite amusement, and his wizardry became a topic of enthusiastic conversation, not only in the neighbourhood, but far and wide. In 1739 Dr. Clayton gave a lecture upon his discovery before the Royal Society, and repeated his experiments for the satisfaction of his learned colleagues.

Such was the discovery of coal-gas and its illuminating properties, but it was dismissed as being only an interesting laboratory experiment. The possibility of turning the discovery to commercial account was emphatically negatived and ridiculed. Accordingly, nothing more was heard of coal-gas for nearly a century. It even lost its novelty as a laboratory experiment and a source of amusement.

Towards the close of the eighteenth century another investigator—who, no doubt, had learned about Dr. Clayton's interesting experiments—took up the issue. This was the famous Cornish engineer, William Murdoch, whose steam motor-car had thrown the superstitious citizens of Redruth into wild hysterics a few years previously. He embarked upon a series of experiments, and in 1792 gave his neighbours another violent shock by lighting his home at Redruth with "spirit" gas obtained from coal.

The practical application of Clayton's discovery created a tremendous sensation, but it was not regarded with equanimity. The timorous Cornishmen conjured up various fates which would befall them if the "spirit" rebelled. They would be burned out of house and home, and at night they retired to bed with quakes and fears. Even if they did not suffer incineration while asleep, they felt convinced that they would be suffocated by the "smoake."

But Murdoch was not the man to be impressed with fears, threats, or alarms. He saw that once apprehensions had been overcome, and when it was proved possible to tame the spirit, that gas-lighting must become a universal friend. Even his own home proved this point up to the hilt, because the light was surpassingly brilliant when compared with the faint flicker of the tallow dip then in vogue. Satisfied with his achievement at his home, Murdoch inaugurated a gas-lighting exhibition in Soho, whence he had removed upon entering the employment of Boulton and Watt, the famous engineers. This demonstration was given during the early days of the nineteenth century, and it aroused considerable attention and appreciation.



THE MODERN METHOD OF LOADING WAGONS WITH COKE

The coke is dropped into the large overhead hopper by an aerial conveyor.

CHARGING AND DRAWING RETORTS BY HAND

This practice is now seldom seen, having been superseded by mechanical methods.

Photos by courtesy of the Commercial Gas Association, Ltd.

But all was not plain-sailing, despite the fact that private residents throughout the country, as well as manufacturers, installed plants for making coal-gas to light their homes and workshops. Opposition arose, and it became very pronounced, but some of the objections were extremely naive, while others were quite rational. Whereas the latter were provoked by fears of fires and suffocation, the former were advanced from vastly different and irrelative motives. Thus, one opposition party vehemently declared that the new-fangled light would deprive Britannia of her ability to rule the waves. Why? Because it would sound the knell of the whale-oil industry—whale-oil lamps were then widely used—and the extinction of this calling would adversely affect the whale fishery, which was declared to be the nursery whence Britain drew her sons to man her fighting ships. As the Napoleonic wars were then raging, this objection met with considerable support.

But adverse public opinion could no more arrest the coming of the coal-gas than it could the recurrence of day and night. A far-seeing and enterprising engineer, who had been engaged in the erection of private plants for the supply of the new light, threw himself enthusiastically into the development and exploitation of the new friend and servant of the community. He saw that if gas-lighting were ever to come into popular favour it would have to be generated upon an extensive scale at central points, and supplied to private houses, factories, workshops, public buildings, and thoroughfares in precisely the same manner as water was delivered.

This energetic engineer, Mr. Samuel Clegg, secured the enthusiastic co-operation of an equally progressive and enterprising spirit in Mr. Winsor. They laid their heads together and decided to endeavour to secure Parliamentary sanction for such a scheme. This decision precipitated a hornets' nest about their ears. They were relentlessly assailed on all sides, and the Bill for the incorporation of the public supply company, which was styled "The London and Westminster Chartered Gas Light and Coke Company," met with vehement hostility from scientist, peer, and pauper, financier and insurance companies indiscriminately. Vested interests objected to the measure in vigorous terms, the street-lamp lighters going out on strike, and the parish authorities emphatically declaring their intention to uproot any lamp-posts and pipes planted in the streets within their jurisdiction.

People could not understand the possibility of conveying the gas through distributing pipes. They maintained that the pipes themselves must be full of flame! Then, should a pipe break—why, look at the terrible calamity which would befall the community! While it raged, the battle-royal was appreciated by only one section of the public—the caricaturists. They made merry over the uproar, Cruikshank and Rowlandson being particularly active and satirical in this direction, the former's "The Good Effects of Carbonic Gas!!!" and the latter's "A Peep at the Gas Lights in Pall Mall" proving especially popular.

The adventures of those who were anxious to introduce gas-lighting for the benefit of the public were exciting and infinite in their variety. But they stood by their Bill, and fought grimly.

Curious to relate, the most pronounced animosity to the project emanated from the so-called pioneers of progress, whose support, one would have thought, would have been given ungrudgingly. This was the leading body of scientists as represented by the Royal Society. To these worthy workers and deep thinkers, the idea of storing gas within large reservoirs was unparalleled audacity, and they ridiculed the proposal unmercifully. Even Sir Humphry Davy sarcastically inquired whether Clegg intended to use the dome of St. Paul's Cathedral as a gas-holder; but the daring engineer retorted that it would not be big enough, and he had his revenge, because before he died he saw gas-holders of sufficient size to be able to receive the dome very comfortably.

Clegg appeared to enjoy the spirited tussle. An objection was the opportunity to demonstrate that the apparently impossible could be achieved. When the lamp-lighters went on strike he took a ladder and lit the objectionable lamps himself, thereby bringing home to the rebellious toilers the conclusive fact that they were not as powerful or as indispensable as they, in the wisdom of their conceit, imagined.

But 1810 brought the turmoil to a conclusion. Parliament granted the charter, and accordingly that year witnessed the birth of the first company in the world which ever secured the requisite powers, or essayed the task, of supplying the general public with gas. The company is still in existence, and ranks as the largest and most powerful of its character, although its title has been changed since the stormy opening decade of the nineteenth century, being now known as the Gas Light and Coke Company of London.

It was not until the promoters of the enterprise settled down to fulfil the claims which they had advanced that they realised the proportions of the problem which they had attacked. There was absolutely no previous experience to guide them. They were creating a new industry, and every step was in the nature of a pioneer movement. In those days metal pipes were unknown. The water supplied by the New River Company flowed through pipes of wood. But Clegg was not dismayed. He built his distributing mains of stone, and the supply pipes of musket barrels screwed together. Explosions and fires were of frequent occurrence, but each calamity of this character was accepted as a lesson, and precautions taken to obviate its repetition.

The methods of running the organisation sound quaint in the light of current knowledge. The meter, which registers the quantity of gas, was unknown, so customers were charged so much rental for each light per year. Clegg recognised the shortcomings of this method, and even turned his attention to the design and construction of a registering device so that the customers might be charged for what they consumed.

By 1813 Westminster Bridge had received its due allotment of lamps and was first lighted by gas. Once the public realised that their objections had come to naught, they seemed to turn completely round, and were speedily assailing the company vigorously for not completing their contracts to install the new lighting system with promptitude. But this concern, in common with many others devoted to a new industry, suffered severely from crippled finances.

The capital ran away like water in carrying out the essential preliminary preparations, and to surmount this deficiency every penny received by the company was turned again into the business. The shareholders were forced to forgo their dividends, but they had the satisfaction of learning that they were building up a huge fabric, a monetary return upon which was certain to come in due course.

Gas-lighting received a decided impetus during 1813. Clegg let himself go with a galaxy of gas-illuminating novelties to celebrate a national event. They made a deep impression upon the public, both among the citizens of, and country visitors to, the metropolis. Unfortunately, the most important device of this character was ruined by the exuberant enthusiasm of one fervent citizen who considered the framework an ideal support for firing rockets!

By this time gas-lighting had become so firmly rooted as an indispensable commodity and convenience that its extension throughout London proceeded apace, the greater part of the metropolis being provided with a network of mains by 1814. It had also forged ahead among the provincial towns, the advantages of the public supply system being widely appreciated. Moreover, the success of the idea in Britain became known abroad, and the system of gas-lighting was exploited in every direction. The methods and devices evolved and perfected by Clegg became tacitly recognised as standards, and were freely copied. In some instances the lessons of accident from which Clegg benefited so profitably were ignored, especially in the United States, with the result that explosions and fires occurred with such exasperating frequency as to jeopardise the extension of this method of illumination.

It is impossible to trace the romantic story of coal-gas within the compass of a single chapter, but there are certain milestones in the history of its development which are of more than cursory significance. In the early days the gas was the solitary article in demand. The other products which arise during the process of distillation were regarded as an unmitigated nuisance. But as the industry settled down, owing to the successful surmounting of the initial problems, and scientists realised that coal-gas, instead of being a dire enemy, was an invaluable friend, offering a remarkable field for investigation and research, the waste products claimed greater attention. First it was found that the solid residue in the retorts, the coke, which remains after distillation is carried out, was not a useless ash or clinker, but that it still retained valuable fuel properties, and was virtually as good for power and heating purposes as the original coal. In some respects it was superior to the latter article, and possessed the overwhelming virtue of emitting no smoke during combustion. Then the viscous black liquid which issues from the coal was discovered to be a valuable wood-preserving agent, one of the earliest applications of this residue being the impregnation of sleepers for railways and the butts of fence posts, which it was found, when treated with this substance, possessed longer lasting qualities than the raw timber.

But the great advance was made in 1856, when a young research chemist, eighteen years old, discovered the first of the aniline dyes—mauve. By this achievement young—afterwards Dr.—W. H. Perkin, F.R.S., created a new industry, the limits of which now, as in those early days, it is impossible to foresee. It was an invention which was destined to create a new line of investigation and research, to build up an industry as important, far-reaching, and wealthy as that of the gas itself, and which was predestined to exert a far-reaching influence upon several other industries, more particularly the textile trades.

Perkin's discovery provoked a situation which it is difficult to parallel in the romance of human endeavour. A demand for the dye arose instantly, with the result that the young inventor, at the age of nineteen, found himself as a manufacturer and pioneer of a new industry. Like the fathers of gas-lighting, he was compelled to undertake considerable research work, there being no previous experience to guide him. Perkin's business flourished amazingly; but unfortunately for the fortunes of Britain, when he retired from activity he left no one to continue his line of labour. On the other hand, the Germans, recognising the far-reaching importance of the aniline dyes, took up the threads of investigation and experiment. Their scientists threw themselves into the new treasureland with whole-hearted zest, receiving every encouragement and reward, whereas British scientific minds appeared to allow the matter to drift, or at least regarded it with an air of indifference.

Under these circumstances it was not long before other artificial dyes derived from coal tar were discovered and made their presence felt in the commercial world. Hard on the heels of mauve came magenta, followed in turn by an array of blues, the first aniline green, and black. A tremendous sensation was caused when Perkin, simultaneously with, though independently of, two other investigators, introduced alizarine, or turkey red. This was hailed as the greatest achievement in this field, second in importance only to the discovery of the first aniline dye, because for the first time the artificial was brought into direct conflict with the keenly demanded natural article. Up to this time the cultivation of madder had been conducted upon an extensive scale merely to furnish alizarine, which was obtained from its root. When the discovery was announced it was received with scepticism, if not indifference, those interested in the natural article maintaining that it would never be superseded by the artificial production. There appeared to be every reason to second this belief, because extreme difficulty was experienced in discovering the best and most efficient methods of applying this dye—a task which occupied several years and called for incalculable patience. But at last success was recorded, and the doom of natural madder, which could not compete with the synthetic article in price, was sealed.

All this time strenuous efforts were being made to produce an aniline indigo. But it appeared to baffle every effort. Twenty years were occupied in this one quest alone, and one firm expended as much as £20,000 to bring the process to success, but failed in the task. The money which has been sunk in the endeavour to extend the number and character of essential dyes from the products resulting from the manufacture of coal-gas is tremendous, and in many instances not a penny has been received in return. Indigo was a dye for which a huge commercial demand existed, but the natural article was expensive, and was rising in price. It was virtually a monopoly of India, where it was raised upon an elaborate scale.

But human perseverance in due course achieved its object. Artificial indigo was converted into a practical achievement, and, as in the case of the madder, the cultivation of indigo fell upon evil days. It is only recently that the Indian industry has experienced a revival and a new era of prosperity. The successful manufacture of artificial dyes from the by-products of coal-gas distillation have wrought many changes, some of which are somewhat interesting. Thus, Tyrian purple was a highly expensive colouring medium until the aniline dye of this tinge appeared upon the market. The natural article was derived from the blood of shellfish, and, as may be supposed, its production under these curious circumstances was extremely costly, and obtainable only in limited quantities. To-day the synthetic dye, which has completely displaced the natural article, can be manufactured cheaply and upon an extensive scale.

The story of aniline dyes forms a fascinating romance in itself. At the moment there are a round thousand different colours which are supplied from this by-product of the gasworks. Each has its individual story of patient investigation, and each represents a distinct conquest of chemical science.

Hand in hand with the extraction of aniline dyes from coal tar has marched the derivation of drugs which are used on every side—such drugs as aspirin, antipyrin, veronal, sulphonal and so forth. Then, again, from the same base we obtain coal-tar sugar, or, as it is commercially called, saccharine, which is three hundred times sweeter than cane sugar.

As a matter of fact coal-gas—and by this term one includes all the articles derived from coal as a result of its distillation—is the greatest friend and enemy of mankind at one and the same time. In addition to the illuminating "spirit" we obtain a wide variety of articles. We get naphtha, which enters into the manufacture of our mackintoshes and other articles of apparel, and is the solvent for indiarubber; benzol, which is a fuel for motor-cars and high-speed explosion engines generally; toluene, used for high explosives; lamp-black; creosote, for treating timber and woodwork so as to give it a greater length of life, as well as forming a dip for sheep and other animals; carbolic acids, for disinfectants and the manufacture of picric acid, which enters into the composition of lyddite, mélinite and other explosives; sodium cyanide, for plating silver and extracting gold; various pigments and paints; aniline dyes; wagon grease; pitch for fuel blocks and use in the electrical trades; tar for paving our roads and as a protective coating for woodwork, felt-roofing and masonry; perfumes and smelling salts; artificial manure; anhydrous ammonia for refrigerators and producing artificial ice; ammonia; and cyanogen gas, which has played a prominent part in the poison-gas phase of the Great War.

We have seen that in the early days the illuminating agent was the pure gas derived from the distillation of the coal. But to-day, if such a term may be used, the raw coal-gas is adulterated—or rather blended—with another gas. This is known as "water-gas," "carburetted water-gas," and is one of the improvements which have been perfected during the past thirty years.

Though a British invention, having been discovered by Ibbetson in 1823, it was first brought into operation in the United States. Its advantages becoming speedily appreciated, it was adopted extensively on all sides, the result being that nowadays it forms part and parcel of every up-to-date gasworks. Water-gas is made by the aid of incandescent coke, steam, and mineral oil, the latter being a residue obtained during the distillation of petroleum. The coke is raised to a bright white heat by means of a blast of air. A jet of dry steam is then turned on to the incandescent fuel, and upon coming into contact with the glowing coke is decomposed into what is known as "blue-" or "water"-gas.

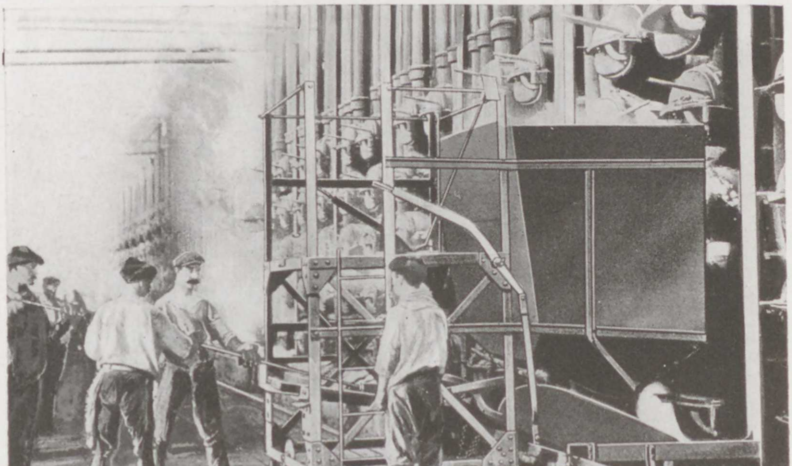
This gas is of no use for lighting purposes, because it is non-luminous. The hot gas is subsequently brought into contact with a fine spray of the oil. Carburation takes place, and in this manner carburetted water-gas is formed. The latter is then mixed with the pure coal-gas and passes into the gas-holder. The main advantage of water-gas is that it cheapens the cost of manufacturing the article which is supplied to our houses, factories, shops and streets. The fact, however, that the illuminating agent is no longer the pure article derived from the coal has led to a modification of the generic name of the product, the article now being known as "town-gas."

Although the illumination by coal-gas upon its first appearance was described as of "the most extraordinary splendour," it must be remembered that this comparison was with the feeble flicker of the rush light and the dim glimmer of the whale-oil lamp, since at that time the illuminating properties of petroleum oils were unknown. Indeed, very little, if anything, was known about mineral oils in those days, although natural or the original "spirit" gas had been known as an illuminant for centuries, especially in China. Accordingly, the introduction of coal-gas necessitated the design of a special type of burner, so as to secure the maximum of light with the minimum consumption of gas. It was Murdoch himself who devised the "cockspur" burner. Subsequently there came the fish-tail and batswing burners which are still used. Many fertile experimenters strove to improve upon these types, but they achieved only trifling and passing successes, their devices being so deficient in the essential features —simplicity of design and operation—as to prevent widespread adoption by the general public.

The vogue of oil lamps, in the latter part of the eighteenth century, induced a Swiss inventor, Argand, to devote his attention to the oil-lamp burner with a view to increasing the volume of illumination for a given consumption of oil. He succeeded, and his burner was extensively adopted owing to the many advantages it offered. When gas had established its popularity efforts were made to adapt the Argand oil wick burner to the new lighting agent. These efforts also terminated satisfactorily. In fact, the burner was brought to such a high standard of perfection as to be considered impossible of being surpassed. Then came the electric light and the spirited

CHARGING A GAS RETORT

Showing the modern methods of introducing the coal by means of machinery.



THE REAR END OF A RETORT

The incandescent coke being withdrawn by machinery to allow a fresh charge of coal to be introduced at the opposite end.

Photos by courtesy of the Commercial Gas Association, Ltd.

struggle for supremacy between the two methods of lighting. While gas triumphed in some parts, electricity vanquished it in others, but it was generally conceded that the era of coal-gas lighting was on the wane, and might be superseded unless some revolutionary idea in gas-lighting was produced.

The revolution occurred. By an accident a new era of prosperity was given to the practice of gas-lighting. In the ordinary burners the gas is ignited merely to burn, the light emitted being the flame resulting from combustion, much upon the same lines as a piece of paper will flare up when lit. But about the middle of the last century a new principle of gas-lighting occupied considerable attention. This was the utilisation of the gas to generate extreme heat, which, brought to bear upon a suitable substance, induced the latter to glow. When heating was raised to a certain point the material threw off an intensely white light.

The substance used for this purpose had to be of a refractory nature—that is to say, it would resist combustion. The first practical experiments were made shortly after the introduction of water-gas, research being stimulated for the simple reason that this gas is non-luminous. Gillard, to whom we owe the water-gas development, was the first to attempt the solution of this problem, because he realised that if he succeeded in this quest water-gas would become additionally valuable. He used platinum gauze for his purpose, and although he succeeded up to a point, the results were without commercial value, for the reason that the platinum speedily became inactive owing to the heavy deposition of carbon or soot upon it.

While this attempt to give the world what is known to-day as incandescent gas-lighting failed, it prompted further investigation of the subject. The first decisive step towards the accomplishment of the apparently impossible came when practical joking in a laboratory culminated in the production of the Bunsen burner. In this burner air becomes mingled with the gas before it reaches the burner, the result being a very hot, blue, and almost non-luminous flame.

Upon the appearance of this invention a French chemist, Clammond, attacked the problem and finally succeeded in employing calcined magnesia as the refractory substance. He devised a mantle of netting, similar to that used to-day, which he called a "basket." This was placed over the Bunsen burner, and the gas was then lit. The intensely hot flame of the Bunsen burner raised the calcined magnesia to a high state of incandescence, causing it to emit a bright white flame. While the first mantles of this description were of the upright type, this ingenious Frenchman also succeeded in adapting his idea to the inverted system of lighting. His discovery was even carried to the initial stages of commercial application, and a great sensation was caused both in London and Paris by the inventor's exhibition of this system of lighting. But Clammond failed to reap a reward from his endeavours, and incandescent gas-lighting suffered another relapse into obscurity.

But in 1885 appeared a patent specification which caused another sensation in the gas world. An Austrian chemist, Carl Auer von Welsbach, was engaged upon some experiments with the rare earths in his laboratory. He was investigating a certain solution into which he dipped a piece of cotton. Afterwards he lighted the saturated material. To his complete surprise he noticed that, although the cotton was burned away, the salt of the solution with which it had been impregnated remained, and what was more remarkable, retained the shape and form of the original cotton material. He also noticed that, when brought into contact with heat, the salt assumed a state of incandescence and emitted a striking illumination.

Although his researches were in a different direction and were not influenced by this brilliant light, its occurrence induced him to pause and to reflect. As a result of his pondering he abandoned the investigation which he had taken in hand, and devoted his energies towards the new problem which had suddenly thrust itself before him. He repeated the accidental experiment, soaking pieces of material, time after time, in the solution of the rare earths zirconium, lanthanium, yttrium and others, and subsequently burning away the combustible fabric. In every instance the astonishing result which he had first detected was repeated.

Then he took to shaping pieces of material in the forms of hoods or caps, which were similarly soaked in the solutions. These he found to preserve their shape after the base had been consumed by fire. The solutions of further rare earths, both simple and in combination, were tested, from which he found that some solutions, when converted into a metallic oxide by burning away the base, gave a more brilliant light than others. This led him to ascertain that the best results were obtained by combining thoria and ceria, and he patiently pursued his tests until he discovered the most satisfactory proportion of the two substances.

Simultaneously he set about discovering the most serviceable form for the mantle, and found that a knitted hose-like foundation of cotton fabric gave the best results. This was soaked in what was known as the lighting fluid, which to-day comprises thoria 99 per cent. and ceria 1 per cent. The proportion of ceria is thus very slender, amounting in a single mantle to a few microscopic grains. But it is the ceria which gives the lighting brilliancy, the thoria giving the fragile skeleton its strength.

When the cotton is burned away the rare earths, in the form of metallic oxide ash, are left clinging together, and the mantle retains its original form, which is maintained so long as no extraneous force is applied, such as a draught of air, a jar, or excessive vibration.

But even in its pre-burnt form the mantle was conspicuously fragile, since the woven material forming the base is thin, light, and delicate. To render the discovery of commercial value the mantles had to be given sufficient strength to withstand the rigors of transport in safety, and this end was accomplished partially by dipping the mantle in a collodion solution.

While the appearance of this incandescent mantle was hailed with enthusiasm by gas-lighting enthusiasts, it was not strikingly successful. The mantles were far too fragile, and their relatively short life in the average home, combined with their expense, caused the invention to meet with pronounced disfavour. The brilliancy of the light for a reduced consumption of gas was incontestable, but the necessity to replace the mantles frequently were held to outweigh any advantages accruing from their use.

Incandescent gas-lighting, however, had received too pronounced an impetus to permit another retirement into oblivion. Other scientists attacked the issue, and they succeeded where the original inventor failed, although the latter, by continuing his work, overcame the disadvantages one by one. It was feared that the cost of the mantles would always remain a prohibitive factor against universal use, seeing that thoria is obtained from a particular sand, known as "monazite," the deposits of which are somewhat scanty, the richest being found upon the coast of Brazil. But the increased demand for the commodity led to improved and cheaper methods for its extraction, with the result that the price of the mantles was steadily reduced.

It was the base which constituted the greatest weakness of the mantle, and various substitutes for cotton were tried. First ramie met with conspicuous favour, inasmuch as it was found to be superior to the cotton. Then another chemist indicated that artificial silk was superior to both cotton and ramie. Another investigator, Plaisetty, found that knitted artificial fibre was better still, and that ammonia was superior to collodion for hardening the mantle. This inventor met with the greatest measure of success, and his original idea, modified and improved with the passage of time, holds the world to-day.

As is well known, the first Welsbach mantle was of the upright type, resembling an attenuated truncated cone, with a small loop at the crown to slip over the crutched top of the rod by which it is held in position. But this system of lighting is erroneous, inasmuch as dark shadows and indifferent light are thrown beneath the burner, such as upon a table, which in reality is the point where the maximum of light should be given. As the mantle was improved in strength efforts to turn it upside down were made, but this problem proved to be far more tantalising than it appears to the uninitiated. Three inventors, working independently, discovered how to achieve the desired end in 1903, and their work ushered in the epoch of inverted incandescent gas-lighting which to-day has such a world-wide vogue.

But in these days the utilisation of gas for lighting in reality constitutes its most subsidiary application. The quantity of gas consumed for this purpose is insignificant in comparison with its other multifarious uses. The gas-stove has ousted the kitchen range for domestic purposes, while the gas-fire is driving the open grate into well-deserved oblivion for heating. But the most extensive applications are to be found in the industrial world. There is scarcely a branch of manufacture where "town-gas" has not effected its conquest. In fact, it has been introduced into many trades in which, for many years, it was considered to be impracticable, and has conclusively established its superiority to the previous methods of heating and the supply of power.

The latter development, which has now attained enormous proportions, dates really from the day when Dr. Otto evolved the four-cycle explosion engine.

CHAPTER IV

The Modern Submarine

THE early 'forties of the nineteenth century were troublous times in Ireland. Riot, evictions, and venomous antagonism to English rule were the order of the day. Into such a world of turmoil, unrest, and racial prejudice there was born in County Clare, in 1842, one whose life's work was destined to play —seventy-two years later—an important rôle in the eternal contest for supremacy between nations.

It is not surprising that this boy, John P. Holland, raised as he was in an atmosphere of hostility to the English, should have become saturated with anti-British sentiment. It was dinned into his ears by relatives, friends, acquaintances, and strangers. The result was that by the time he was emerging from youth into manhood he had become a hot-head among hot-heads, consumed by one burning desire—the overthrow of British domination and the release of his native country from the yoke of English tyranny, as it was called.

But young Holland had not only inherited pronounced political ideals. In his early years he also revealed the family traits of industry, genius, and dogged determination to succeed against the most adverse circumstances. Although his parents were not well blessed with this world's goods, they extended him the best education which they could afford and which the local facilities could provide. Naturally, the curriculum was somewhat limited, but in combination with self-education, young Holland was able to secure the position of teacher.

While teaching, young Holland, then twenty years of age, became imbued with an idea. He had been reading about two American inventors, Bushnell and Fulton, and their trials and tribulations in forcing their respective inventions upon an unsympathetic world. One of their fields of investigation particularly fascinated him—submarine navigation. It did not appeal to him from the commercial point of view, but essentially in the character of the assassin of the seas, wherewith to strike surreptitiously at the vessels comprising the British Navy, and thereby wreck Britain's rule of the seas.

The feasibility of such a plan of campaign secured such a firm grip upon young Holland's mind that he already pictured warship after warship flying the hated ensign suddenly foundering from underwater attack. These mental illustrations prompted him to attempt where Bushnell and Fulton had failed. All his spare moments were devoted to the preparation of the plans and designs for a submarine capable of achieving such an intensely desired end. He worked far into the night, physical exhaustion being warded off by the imagination that he had struck the correct line of construction. When his designs were finished he was confident in his own mind that he had solved the problem of underwater navigation, and with the ardour of the young enthusiastic inventor, zealously canvassed his friends and acquaintances for the necessary financial support to build such a vessel. But

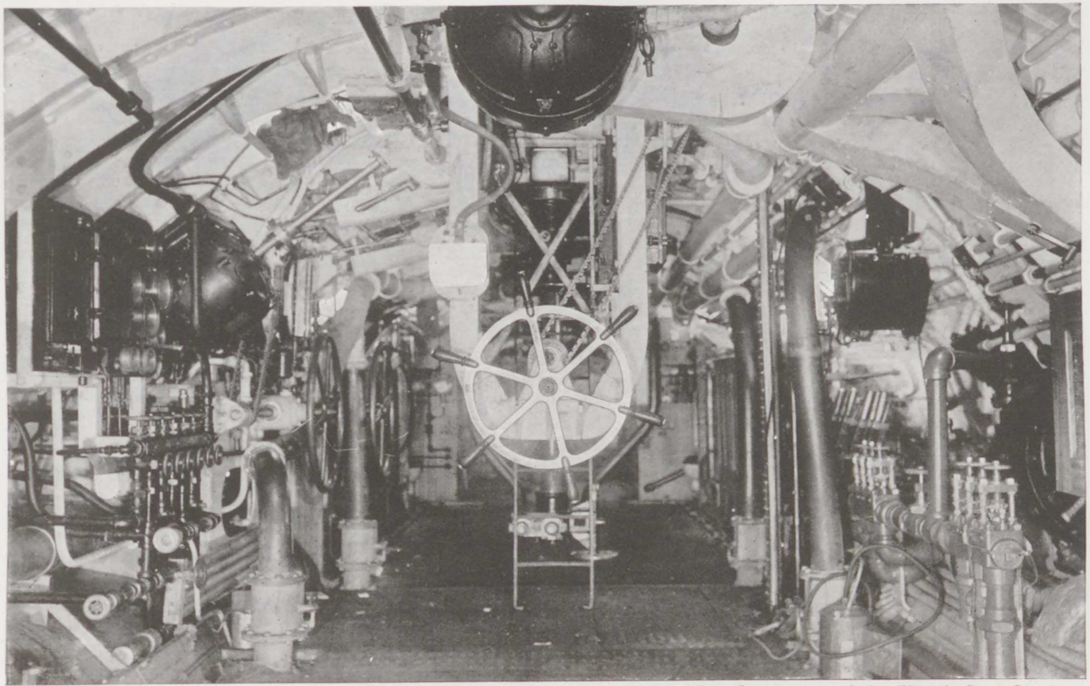


Photo by courtesy of the Electric Boat Company.

THE ENGINE ROOM OF A HOLLAND SUBMARINE

even his most frenzied friends refused to listen to him. They considered him crazy, and his underwater vessel merely the figment of a disordered brain.

After two years' heartless endeavour to stir up his compatriots to co-operation, he shook the dust of Ireland from his feet in disgust. He would go to America, where the Irish plotters were more energetic and enterprising. But misfortune appeared to cling to him even in the land from which he expected so much. Shortly after landing at Boston he met with an accident, which necessitated a sojourn in hospital. Here he whiled away his tedium upon the improvement of his ideas and designs. It became noised abroad that a newly arrived young Irishman had invented a submarine, and naturally he became the quest of the newspaper men. They listened quietly to his fervid stories, admired his inflammatory and unquenchable hatred of Britain, and inspected his designs with sympathetic interest. But they did not announce him to the world as an inventor whose ideas would revolutionise the whole trend of naval science! They merely ridiculed him mercilessly.

Yet this attitude left Holland unmoved. He had supreme confidence in his great idea, and would not be dissuaded from its further prosecution by ridicule, indifference, or even antagonism. Every spare hour was devoted to perfection of details in the drawings, while he lost no opportunity to canvass for practical sympathy in the form of funds wherewith to build such a boat. But the American Irishmen appeared to be as unimaginative as his countryfolk in County Clare.

In 1873 he took up the position of teacher in the parochial school at Paterson, New Jersey, the hotbed of conspiracy against Britain and all her works. Failing to secure financial assistance to build his boat, he resolved to complete its construction as well as his limited funds would permit in order to demonstrate his idea in a tangible form, arguing that when convincing testimony as to the practicability of his idea was offered, he would be able to command greater sympathy from financiers and speculators.

The vessel was built of wood, laboriously caulked to render it watertight. It followed the form of the cigar in its lines, and was driven by a petroleum engine. It was drawn from the quarters in which it was built to the bank of the Passaic River by a team of sixteen horses to be launched. But this ceremony proved a tantalising fiasco. It stuck in the mud, and for a time refused to be withdrawn from that slimy couch. At last it was got afloat and was submitted to frequent tests. But however feasible the idea might have been—and Holland always maintained that it was built fully in accord with his principles—the trips were neither conclusive nor illuminating. The boat continually leaked, while the petroleum engine manifested a decided determination to refuse to work, breakdowns being maddening in their frequency. These disappointing trials revived the attitude of ridicule and scepticism, which became more acute than formerly. At last, in sheer desperation, Holland dismantled the craft, and sank the hull in four feet of mud at the river's edge.

Still Holland did not despair. He had come into intimate touch with the leaders of the great scheme for the liberation of Ireland. He was elected a member of the innermost organisation of the secret society scheming for Britain's downfall, and here he secured the ear of the very men who could assist him. His fortune appeared to have changed. The conspirators had completed their plans for the invasion of Canada and possibly of Ireland, but there was one great—and to them insuperable—obstacle which would prevent the realisation of their dreams—the British Navy. How could this difficulty be overcome?

Everything turned upon this issue. Holland saw the golden opportunity for which he had been waiting patiently through the years, and grasped it boldly. He introduced his submarine idea, outlined a proposal he had evolved, and expatiated upon the helplessness of the big warships of the British Navy against puny antagonists which would be capable of approaching their quarries stealthily and safe from discovery to launch their torpedoes.

The conspirators, baffled, and not knowing how otherwise to solve the problem which was balking their great project, decided to give Holland's suggestion a trial. They possessed a secret fund of £14,000, which could be devoted to the construction of the submarine; and without any delay the work was taken in hand. Within a short while it was completed, but it was not a success. The construction was at fault and the machinery was placed in the wrong position, causing the craft to cant her nose above the stern. It proved impossible to trim her so as to obtain absolutely perfect equilibrium. On the other hand, she fulfilled all the rest of the claims which Holland had advanced. She submerged easily and readily, and came awash without the slightest hesitation when desired. She moved underwater and answered her helm. The one-man crew within related that when submerged he experienced no difficulty in breathing, and that the supply of air from the compressed air reservoirs worked satisfactorily.

This vessel was considered to be so promising that it was decided to push ahead without delay with a second, improved and larger, craft. The defects which had been manifest in the first vessel were capable of elimination. To ensure this second craft being completely satisfactory, an arrangement was consummated whereby Holland relinquished his school duties to devote his sole energies to the building of the new boat, the secret fund being drawn upon to reimburse him for his loss of salary as a teacher.

The submarine was duly completed, and it proved a decided advance upon its predecessor. There was accommodation for a crew of two, Holland himself taking the helm while his assistant served as engineer during the trials. The boat followed the Fulton principle of design and operation, vertical and horizontal rudders serving as the control. The boat aroused distinct interest owing to the facility with which she submerged and rose to the surface. This vessel virtually ushered in the diving principle which is the outstanding characteristic of the submarines of to-day. Hitherto the practice was to sink and to rise upon an even keel, the disadvantage of which was the time occupied in submerging.

With this little craft Holland performed various evolutions in the waters washing New York City, and was a constant source of wonder, fear, and amusement among those travelling in the ferries and upon the excursion boats. Only one serious trouble was experienced, and that was in connection with the engine. The internal combustion motor of those days, however, was far from being reliable, but this circumstance was rightly ignored in considering the merits of Holland's invention, inasmuch as the power plant was obviously open to, and was certain to undergo, considerable improvement as knowledge was acquired.

The newspapers which had hitherto derided Holland's idea of reducing Jules Verne's phantasy into grim reality followed the evolutions of this boat with ill-disguised interest. Ridicule gave way to speculation concerning the influence of the submarine upon future warship and naval developments. The boat lacked a distinctive name, but the newspapers supplied the deficiency by christening it the "Fenian Ram," from the fact that it had been built at the direct instigation and with the money of the Fenian movement in the United States to further the Fenian dream of a liberated Ireland.

The plotters had been successful in preserving their activity in this field a tight secret. But the manœuvres of the boat in the waters of New York Bay, and the pertinacity of the press in probing the mystery associated with its construction, laid bare the whole conspiracy. The inevitable followed. The Irish patriots have always been assailed as lacking in constancy and with failing to pull together for a prolonged period. Moreover, the golden opportunity to strike at England had passed before the boat had been completed. Some dissatisfied members of the conspiracy, who were not *au courant* with the innermost workings of the organisation, commenced to ask inquisitive questions concerning the condition and use of the secret financial fund. Disintegration set in, opposing factions springing up and fighting one another with all the grim determination and hatred with which they had been attacking England.

Even the "Fenian Ram" did not escape the vengeance of one faction. One night a small party of malcontents stealthily made their way to the spot where the little submarine was moored. They cut the ropes and towed the capture to a prearranged point elsewhere. What the idea governing this action was no one appears to have known. Possibly the malcontents intended to run the submarine campaign by themselves and unaided. In some quarters it is asserted that Holland was a party to this surreptitious capture of his boat; but, on the other hand, Holland, who had grown disgusted with the unexpected turn of events, vehemently declared that the boat was taken without his knowledge or authority. Indeed, he went so far as to accuse the malcontents of stealing his vessel. The latter assertion is undoubtedly the truth, because the new owners never sought Holland's assistance in their subsequent operations. They endeavoured to master the handling of the submarine themselves, but as no one knew the slightest thing about the little boat and her control, they cut a sorry exhibition, as may be supposed. At last, disgusted and piqued at their failure, the malcontents hauled the boat out of the water, ran it into a shed, and covered it up. And there the first successful Holland submarine has rested ever since.

The Fenian movement collapsing somewhat ignominously, all further labour with the submarine on their behalf became unnecessary. Holland was again reduced to his own exertions. The years slipped by, and his name, together with his boat, became almost a memory, more particularly as his achievements appeared to sink into insignificance beside what was being accomplished by certain European inventors who had embraced the problem of submarine navigation and were pursuing the solution of the problem with infinite zeal and not handicapped by lack of financial resources.

In 1895 the United States, thinking the moment had arrived for attacking the issue from the point of national defence, called for designs for a submarine to be constructed at the expense of the country. Virtually it was a competition, inaugurated with the express purpose of stimulating American inventive zeal. Numerous designs were submitted, but only one attracted the attention of the Government officials. The identity of the individual who submitted the accepted drawings was investigated, and to widespread surprise was found to be John P. Holland.

Arrangements for constructing the boat were completed, the inventor succeeding in enlisting adequate friendly co-operation to enable a small company to be organised. But the work did not proceed smoothly. Holland regarded his plans with pride, but the naval engineers selected by the authorities to supervise construction did not see eye to eye with him. In their estimation Holland was an inventor and not a trained engineer, which certainly was true; but at the same time Holland had devoted practically the whole of his life to the subject. Though he may have been deficient in technical knowledge, he was certainly possessed of a greater amount of common sense, and certainly knew more about the subject than the interfering officials who would persist in revising his drawings, introducing this and that according to fancy. To aggravate matters Holland, who was not particularly robust, fell ill, and was unable to devote so much attention as he would have liked to the realisation of his dream.

When Holland saw the *Plunger*, as she was called, before she took to the water, he prophesied that she would prove a failure. He pointed out her weak points, and why this or that alteration in his design would prove unworkable. He even narrated that no one would ever be able to go under the water in her because the internal temperature would be beyond human endurance. As may be supposed, Holland's criticisms were regarded with amusement by the so-called superior technicians; but, to the dismay of the latter, the *Plunger*, when submitted to her trials, failed for the very reasons which Holland had related. The submarine was a dismal failure, the responsibility for which Holland might very justly have placed upon the shoulders of the interfering Government officials. But his disgust was so profound that he decided to sever all connection with the Government, and adopted the most efficient means of consummating this end and of asserting his complete independence. On behalf of his company he returned the £19,000 which had been paid by the Government for the boat, and took it back, thereby closing all avenues for future altercation.

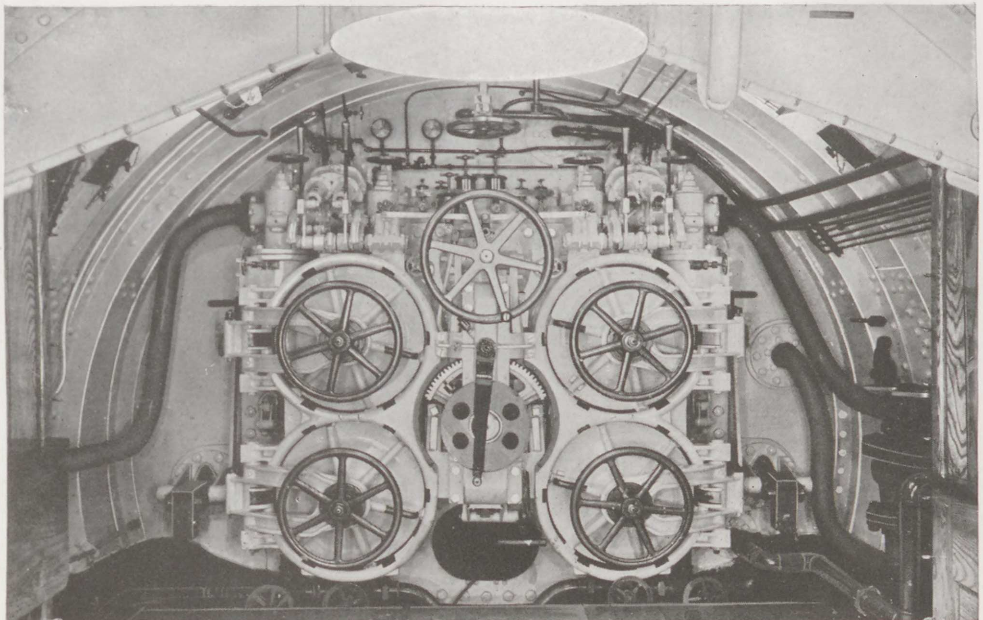


Photo by courtesy of the Electric Boat Company.

THE BOW TORPEDO TUBES OF A HOLLAND SUBMARINE

Bitterly disappointed and mortified at the unexpected turn which affairs had taken when success appeared to be within his grasp, Holland decided to make one more bid for Fortune. He suggested to his colleagues that a submarine should be built as a speculation. If it failed, then he would abandon all further interest in the subject; while if it succeeded—well, the possibilities were illimitable. This win-or-lose spirit appealed to his colleagues, who assented to his proposal, together with the second condition, which Holland laid down as absolutely indispensable. This was the construction of the boat strictly from A to Z according to his own ideas and under his own supervision. He had had enough of so-called technical experts and their incompetence when ranged beside a project about which they knew nothing.

This new vessel was taken in hand in 1898. It was a small craft measuring nearly 54 feet in length by 10¼ feet beam and displacing 70 tons when submerged. She was fitted with a four-cylinder petrol motor developing 50-horse-power, which was adequate to produce a maximum cruising speed upon the surface of 6 knots, at which speed she was capable of travelling 200 miles upon a single charge of her fuel tanks. For underwater propulsion she was fitted with a 50-horse-power electric motor with which she could travel 20 miles when submerged at a speed of 5 knots, which was equal to about four hours' continuous submergence. The armament comprised a single torpedo tube.

This vessel created an intense sensation upon her appearance. At last Holland had been able to substantiate his claims by producing a vessel strictly according to his designs. The manœuvring capacities of the little boat, her rapidity in diving and rising, and her control caused naval men to marvel. The Government, which had assumed an indifferent attitude towards submarines as a result of its experiences with the *Plunger*, was somewhat shaken by the unexpected development. It was realised that Holland certainly did know, as he had steadfastly asserted, more about submarine designing than any of the highly paid technical officials. The authorities subjected the little boat to exhaustive tests, Holland handing her over for this purpose, and were so impressed by her merits that they offered to buy the boat outright. She was sold to the Government for £30,000, and although the builders lost heavily over the transaction, the vessel having cost them some £45,000 in material and labour alone, they tolerated the loss. The *Holland*, as she was called, was admitted to be an experimental vessel, built exclusively to prove or disprove her creator's claims. He had succeeded, and the future success of the company appeared to be assured, especially as the Government a few months later completed an order for six similar craft, though of larger proportions and higher power, the cost of the same not to exceed £34,000 each.

But this was not all. The British Government was watching the developments with the *Holland* very closely, and, realising that the submarine had indeed issued from the chrysalis stage of experiment, and had become a fighting unit of incalculable possibilities, the right to construct vessels of this type was acquired for the British Navy, and five vessels were built. It was indeed a somewhat strange irony of fate that Britain, for the overthrow of whose naval supremacy Holland had striven zealously for nearly thirty years, should ultimately acquire his invention to render her dominance of the seas more secure. So far as Britain is concerned, Holland's designs were purchased merely as a basis for the construction of a submarine fleet. With the experience gained we have evolved our own type, which developments Holland, with his inexplicable pertinacity and faith in his own abilities, regarded as vastly inferior to his original conception.

About the same time the designs were also purchased by Japan, who, in the foundation of her submarine fleet, was disposed to follow Holland's designs slavishly. They made him a tempting offer to go to Japan to supervise the building of the first vessel, but he refused. Instead, he drew up the designs specially for his latest customer in his own home. Other nations were also anxious to secure the advantages of Holland's success, and in this manner was ushered in what may be described as the era of the submarine fighting ship. In the hands of other workers, the Holland vessel has been improved out of recognition and advanced to a stage exceeding even his most sanguine anticipations.

Holland never lived to see the actual results his invention was able to achieve. Within a fortnight of the declaration of war in 1914, he crossed the Great Divide. Had he lived a few months longer he would have had every cause to revise many of the opinions he had strenuously cherished against all opposition for many years. He blindly believed that the submarine would render the waters so unhealthy as to bring about the speedy subjection of any Power depending upon its warships. In his eyes the submarine was absolutely invincible. He never appears to have given a thought to the possibility of effective counter measures being evolved and coming into existence.

Holland was a strange personality, but a typical inventor. His faith in his creation was unique, while he always maintained that his designs were superior to those which any other man might evolve. In 1904, owing to differences arising between himself and his company, he retired from all active participation in submarine construction. When he found that with the accumulation of experience and knowledge radical departures from the lines he had laid down with all the austerity of the Medes and Persians were being made, his wrath revived. He condemned the American submarines of the latest designs as "death-traps," and entertained but very indifferent opinions concerning those submarines for other Powers which had been evolved from his original Holland. He died a bitterly disappointed inventor, because no one would entertain his criticisms seriously. While Holland cannot possibly be described as the inventor of the submarine—seeing that Bushnell, Fulton, Bauer, Garrett, and others had wrestled with the problem previous to his success—the fact that the majority of the Powers have created their submarine fleets upon the foundation which his invention offered entitles him to be called the "Father of the Modern Submarine."

CHAPTER V

The Dawn of the Electric Traction Era

THE wonderful development of the railway, once its advantages had become realised, emphasised the urgent necessity to speed-up and to improve all existing systems of land transportation which were then in operation. By the invention of George Stephenson distances became shrunk to a remarkable degree, and the saving in time did not fail to impress a public which from times immemorial had been accustomed only to the comparatively slow movement incidental to animal travel. In fact, horse-drawn vehicles, even of the speediest type, such as the mail-coach, were ignored, and in a short time became little more than curiosities except in out-of-the-way parts of the country.

The railway appeared at a critical moment. Efforts were being made to accelerate movement, especially in towns and cities, by means of railways laid down in the streets. Naturally, ambition did not soar beyond the limits of employing horses for the haulage of these vehicles, but even then higher speeds were possible by drawing a vehicle along a pair of rails than by time-honoured methods, because there was less friction. Street railways were just commencing to catch the public eye when the steam locomotive made its début. The new force, although demanding its own particular right of way or thoroughfare, effectively relegated the idea of planting rails in the public highways to oblivion. Indeed, one of the most ambitious inter-urban projects of this character, a street tramway between Wandsworth and Croydon, ultimately to be extended to Reigate, and which was promoted with the express idea of facilitating the distribution of coal and merchandise in general throughout the southern district of London, was abandoned, and ultimately swallowed up by the new steam system of transportation, the greater part of the line being incorporated in the London, Brighton and South Coast Railway.

It was the United States which impressed the value of street railways or tramways, as they are more popularly described in these islands, upon the world at large. The Americans appreciated the circumstance that there was a vast difference between the railways so called, and the street facilities of a similar character. The former met the requirements for connecting up towns and cities, while the latter offered a means of enabling the public to move about within the confines of the town or city and its immediate suburbs expeditiously and inexpensively. Accordingly, the first comprehensive inter-urban tramways system was commenced in 1831 in Harlem, New York City, and the success of this initial experiment proved so overwhelming that it was promptly followed by other cities in that country. Naturally, horses were employed for haulage purposes, but the convenience of the system was the outstanding factor which appealed to the general public.

Upon the subsidence of the railway craze in Britain attention once more became centred upon tramways, mainly through the energy of an American, George Francis Train. In 1858 and 1859 he secured the requisite consent to lay down short lines in various parts of the country. But his scheme proved a dismal failure, the rails projecting above the surface of the roadway—thereby offering an obstruction to other vehicular traffic—being the most pronounced objection to the idea, although there were other defects. In course of time these disabilities were removed in the first line laid down—namely, at Birkenhead—and this initial line forms part and parcel of the system now in operation. But in London the opportunities to eliminate the objectionable features were not extended, and the rails were torn up.

Yet it was generally agreed that tramways would have to come into use to facilitate inter-communication, and to afford the working classes the opportunity to pass to and from their work cheaply and expeditiously. The tramway had the great advantage over the railway even in this field of traffic. Whereas the latter was able to stop only at certain points to set down and to pick up traffic, the former could achieve the same end at more frequent intervals, and virtually carried the passenger to and from his door. Again, tram-cars were able to follow one another in close succession, so that a more frequent service was secured.

But the limitations of horse haulage were only too apparent. Under the most favourable conditions the travelling speed could not exceed six miles an hour. Moreover, the running and maintenance expenses were heavy. Inventors and engineers, realising the rich field which had now been opened to them, turned their attention to the question of improving and accelerating street traffic. Steam was advocated as superior to animal traction, but was promptly ruled out of court, visions of the public thoroughfares being converted into roaring railways precipitating a hostile attitude from the powers that be. Besides, there were many technical difficulties which assumed a forbidding aspect. Gas, compressed air, and finally the cable system were tried in turn. Although an illustration of each system of propulsion is afforded in one country or another, it was the cable method which secured the greatest measure of success, but only for a time. The cable tramway, comprising an underground endless travelling cable which could be gripped and released by an apparatus on the car, was the revival of one of the oldest ideas for the movement of vehicles without animal power. In its revived form it first attracted attention because it offered a means of moving tramcars up and down hills which were beyond the capacity of horses.

While the advocates of the cable system were enforcing their claims upon the tramway world, a new means of accomplishing this end was attracting the attention of inventors and engineers, which, it was realised, if carried to perfection would constitute an ideal traction system for tramways.

In 1842 a Scottish engineer, Davidson by name, and hailing from Aberdeen, had indulged in an experiment upon the Edinburgh and Glasgow Railway, as it was then called, but which is now incorporated in the North British Railway, which had aroused more than casual attention, especially in certain circles. With a small car of his own design he had carried a full load of passengers at a speed of four miles per hour. It was a single vehicle and completely self-contained. The smoothness of its running, the absence of smoke, and the simplicity of its control, impressed all those who made the trip. Naturally, there was decided curiosity as to how the inventor had induced the vehicle to move, seeing that neither steam nor gas was used. The riddle was solved when the engineer explained that the car was driven by electricity.

But the engineer from Aberdeen, although he had hit upon a brilliant idea, was far before his time. He was compelled to rely upon batteries for his current. This was fatal. The batteries were crude, bulky, and weighty, while the amount of electric energy which they could store for a vehicle of given weight and dimensions was severely restricted. But the essence of the test was that electricity could be so harnessed as to be induced to propel a vehicle along a pair of rails, and that steam possessed no prerogative in this direction.

Davidson's achievement, although of little or no commercial value at the time, caused busy, fertile minds to ponder deeply. If the batteries could be improved, decreased in size and weight, and their capacity could be increased, under these altered conditions there was a possibility of the idea being turned to profitable account, even if its uses were somewhat limited. Davidson's trials with this electrically driven car attracted the interest of engineers in all parts of the world, and of two men in particular. The one was the well-known German electrical scientist, Werner von Siemens, and the other was Thomas Alva Edison. Yet, at the time, neither could advance the idea to any pronounced or practicable degree.

Electric propulsion of vehicles was brought within the range of possibility for the first time in 1870, when Gramme introduced the dynamo. True, it was a somewhat crude contrivance, but nevertheless it offered a new feature in the science of electricity, and provided a new field for experiment and research, of which full avail was taken, especially by the two brilliant workers above mentioned. Both attacked the issue from the point of adapting Gramme's invention to electric propulsion, and both achieved success about the same date.

At the Berlin Exhibition, held in 1879, one exhibit aroused the attention of all. This was what might be described as a kind of miniature railway running through the grounds. It was a short length of line, only some 600 yards in length, but it proved a powerful draw, the majority of visitors seizing the chance to make a trip over it.

The railway became the focus of attention because of the novel locomotive which hauled the three trucks which provided seating accommodation for thirty passengers. It was a diminutive steed, mounted upon four wheels—in fact, was so small that the driver sat upon the top of it. But the little electric engine of 3 horse-power—for such it was—proved capable of hauling the full load at a speed of four miles an hour. Between the usual pair of rails was a third rail. This acted as the feed-rail, pumping electricity into the dynamo which acted as a motor, and the power generated by which was transmitted through gearing to the driving wheels.

In the meantime, Edison was completing arrangements for demonstrating an electric locomotive which he had devised. The track ran round the grounds surrounding his laboratory, which at that time was at Menlo Park, New Jersey, and was about 600 yards in length—about the same as the line at the Berlin Exhibition. The locomotive was about as unlike our modern conception of such a machine as could be conceived, comprising a deck car 6 feet in length, on which was placed the 12 horse-power dynamo acting as a motor, together with gearing and other devices for control and the transmission of power to the pair of driving wheels, which, somewhat larger than the trailer wheels, were connected to the latter by side rods. The first test was not exhilarating, because the friction pulley and belting transmission system which Edison had incorporated failed to act up to its work. Improvements were made without delay, and as events proved, scarcely a day passed when some modification or other was not found to be imperative. Still, the electric locomotive achieved its designer's ends. It hauled three cars over the undulating zigzagging length of line, which formed probably the craziest railway that ever was built, but which was laid out in this manner for the express purpose of submitting the idea to the most exacting tests.

Strange to relate, the Americans, with very few exceptions, did not regard this latest illustration of Edison's fertility with enthusiasm. To the average person who had the privilege of making a trip, it appealed in the nature of a sideshow at a popular exhibition, comparable with "shooting the chutes," or "looping the loop." Only one man appeared to have any faith in it, and he was one of the foremost railway magnates of the day. Being on terms of close friendship with Edison, he prevailed upon the latter to develop his idea. He went so far as to indicate its possible spheres of application in conjunction with steam roads—for the maintenance of railway communication through sparsely peopled and undeveloped territories, where it would not pay to lay down steam-operated railways. This railway magnate displayed his confidence in the new idea to such a degree as to undertake the building and equipping of fifty miles of electric railways to serve as feeders to the system over which he had control, provided Edison completed experiments upon a more elaborate scale and attained speeds of sixty miles an hour.

In the meantime things began to move in Europe, and, curiously enough, the British were more enterprising in this direction than is generally supposed. Hard on the heels of the demonstration at the Berlin Exhibition, a company was organised to build a railway six miles long in County Antrim, to be electrically operated. While this project was in hand a small railway one and a half miles in length was laid down between Lichterfelde and Berlin, which was opened to the public, and was thus the first electric line to be brought into service for the benefit of the community. About the same time permission was granted to build a short length of line along the foreshore of Brighton, which was opened to the public in 1883, and this was the first electric railway to be opened in England, the Irish railway preceding it by a few months.

Edison, continuing his experiments, built a second locomotive in 1882. This bore a closer resemblance to its steam rival, seeing that its mechanism was covered by a semicircular bonnet somewhat reminiscent of a boiler, while there was the usual driving cab. With this locomotive innumerable tests were made and high speeds were attained. Incidentally, mishaps and upsets were of frequent occurrence, the engine jumping the track at the curves whenever high speeds were attempted. In fact, Edison appears to have taken an uncanny delight in treating experts who were dispatched to Menlo Park to examine and to report upon his electric railway to unrehearsed and hair-raising thrills. There was a sardonic humour about Edison's emphatic declaration concerning the railway being "perfectly safe," despite its twists, kinks, banks and bridges, as a derailment invariably constituted an incident in a trial-speed trip. The impressions of those who bought experience were invariably the same—they described the sensation as glorious, the control simple, and the speeds exhilarating, but always closed their written opinions with the statement, "*and we ran off the track!*" It appeared as if the last-named result constituted an indispensable feature of the journey. However, no bones were broken upon the Edison demonstration electric railway, so that in the long run favourable reports of a guarded nature were invariably dispatched to those who desired information gathered on the spot.

Of course, the derailments could be easily explained. They arose from the curves being too sharp and the locomotive being too "stiff" for the speeds attempted, both of which defects could be easily and completely eliminated in actual practice.

Despite the elaborate trials carried out by Edison with the express purpose of usurping steam from railways, the Americans as a whole considered it more adapted for another field of transportation—*tramways!* Frantic search for a cheap alternative to animal traction was being made, and here, apparently, was the solution of the problem. The cable, though an improvement upon the horse-drawn vehicle, was far from being satisfactory. Accidents and breakdowns were too numerous. But electricity offered an ideal system of propulsion. It possessed the necessary elements—simplicity of control, smoothness in running, high speed, rapid acceleration and de-celeration, and ability to handle heavy loads and upon all kinds of road. The question was the delivery of the necessary current from the generating station to the motors mounted upon the car. Hitherto, all attempts in this direction had been made with a third rail laid between the two running rails. But while such an arrangement was feasible upon a trunk railway which possessed its own right of way, and which was closed to other traffic, a street was open to one and all indiscriminately. Consequently, the third rail was out of the question, unless electrocution of every man and beast who trod upon the rail was a secondary consideration.

Ultimately the question arose: Why not sling the conductor in the form of a wire through the air and above the track, collecting the current therefrom by a suitable device? There was no technical objection to this method. The only possible argument against it was upon æsthetic grounds. Would the civic and municipal authorities permit posts to be planted in the streets and wires to criss-cross the highways, even at a height of 15 to 20 feet? Some cities opposed such a solution of the difficulty tooth and nail. It incurred setting up a dangerous precedent, and if the practice were once commenced there would be no saying where it would end, or what would constitute reasonable limitations.

However, one city demonstrated that it was not prepared to brake the wheels of progress. Here was a decided advance upon the horse-drawn tram, in its infancy, and which ought to be encouraged because it was certain to prove beneficial to the community. Improvements were bound to be recorded, and the franchise could be so worded as to facilitate the removal of the overhead wires whenever an equally reliable and effective alternative method of conducting the current from the generating station to the car was perfected.

The City Fathers who assumed this logical and liberal attitude were those responsible for the welfare of Kansas City. Here the first length of electric tramway was brought into public use in 1884.

The success achieved at Kansas City impressed the other communities upon the North American continent. Lengths of line working after this method were laid down, but it was not until 1887 that a comprehensive complete network of electric tramways for a city was taken in hand. This was carried out by Mr. Frank Sprague for the city of Richmond, Virginia. It comprised eleven miles of line, which were opened for public traffic in February, 1888, proved a great commercial success, and have been in operation ever since. The current was collected from the overhead conductor by means of a pole, at the upper end of which was a small wheel which ran along the underside of the wire. The current thus gathered passed to the motors and returned through the running rails to the generating station. From the fact that the current was collected from the conductor by a trolling or revolving device mounted upon the end of the pole, extending upwards from the roof of the car, this system of operation became known as the " trolley," which distinction is still maintained.

By this time it was recognised that the electric tramway was destined to become the deciding factor for the development of outlying districts into residential centres, for all classes of the community, thereby avoiding congestion in the towns and cities, which had been attaining hazardous proportions because the workers were compelled to live as near as possible to the scenes of their labours.

The electric tramway has played a vital rôle in the growth of American towns and cities. It has enabled the boundaries to be pushed farther and farther outwards. It has developed highroads which otherwise would never have come into existence. Many a swath has been driven through woods, fields and marshes to carry, in the first instance, a pair of rails for the tramcars. For years, perhaps, this road has seen little other traffic, and has been existent more in name than reality. But in time the necessity to fashion the road according to modern ideas has arisen, with the result that, ultimately, what was first merely a channel for the tramcar has developed into a main artery for the movement of all vehicular and pedestrian traffic. The tramway has been the pioneer in opening up new outlying areas.

Photo by courtesy of the British Thomson-Houston Company, Ltd.

RIVALS !

A race between steam and electrically driven trains. The photograph shows the electric train, going at 61·6 miles an hour, drawing away from the steam locomotive.

When the trolley system was suggested in England it met with uncompromising hostility. Antagonistic criticism — the disfigurement of the streets — arose on all sides. The circumstance that such objection was tantamount to attempting to arrest the motion of the wheels which send the world round was foolishly ignored. It was not until 1891 that permission was granted for such an installation, and the city of Leeds led the way. Practical experience revealing that the evils of overhead wires were more imaginary than real, a more complacent attitude was generally assumed. The day of the horse-drawn tramway had passed. Industry and the imperative necessity to relieve the extreme congestion in crowded towns and cities demanded that electric traction should be embraced. The result was that other towns speedily followed the example of Leeds, and the trolley system was even brought up to the boundaries of the metropolis itself.

Within the confines of the largest and busiest cities the objections against the trolley prevailed, and this hostility was as pronounced in the New as in the Old World. All things considered, there was logical excuse for this attitude. An alternative system was available—the laying of the conductor in an underground conduit with a slotted third rail, through which the collector underneath the car could pass to gather the current. It was virtually an inversion of the trolley system. But, as experience has taught, the overhead method is simpler and cheaper to instal and to maintain, while at the same time it is not so easily disorganised as the underground alternative, although this latter drawback is not so pronounced in Britain as in other countries.

But while the overhead and underground conduit practices prevail, they do not monopolise the methods of tramway operation. In some instances, instead of the collector of the car being in constant contact with the conductor, current is picked up at intervals. Plates or studs are set in the roadway at certain intervals and over the underground conductor. Normally, these contacts are free from the conductor. When the car reaches a stud a magnet on the car repels the plate, driving it towards the cable beneath, until a contact with the latter is established.

The current now flows up through the stud, to be collected by a skate carried beneath the car. When the skate has passed, the plate returns to its normal position flush with the road surface, and free of the conductor below. Consequently, it is " dead," and one may tread on it with safety. In this system of operation it will be seen that the car is really driven forward by a continuous succession of intermittent boosts, the current derived from one stud being sufficient to propel the vehicle to the succeeding stud.

The benefits accruing from a well-laid-out system of tramways may be appreciated even in Britain. Circular routes provide attractive pleasure trips through interesting or entrancing country, enabling one to stretch the lungs with pure air with the minimum of physical effort. But it is in the United States where the greatest advantages of electric traction are revealed. Higher speeds are permitted there than here, with the result that in the rural districts, where the highways are practically free from other traffic, the tramways are in a position to compete with suburban trains, and frequently exceed the latter in speed over the short-distance runs by notching 30 miles an hour. In the more densely populated eastern States, it is possible to cover several hundred miles by tramway, the individual systems in a chain of towns having reached out to meet one another, the passenger only being called upon to change cars from time to time as successive networks are reached.

The growth of electric tramways in the United States has been truly phenomenal. In 1890 there were not more than 1,000 miles of these street railways in operation. But from that year the growth has averaged about 3,000 miles of new lines per annum. By 1895 the new form of transportation through the streets had reached what might be described as its standard stage. Sufficient experience had been acquired to establish staple designs for the fundamental features. In the latter year some 25,000 electrically driven tram-cars were in operation, the motors of which represented in the aggregate approximately 500,000 horse-power.

By the closing year of the nineteenth century electric propulsion in this field had conclusively demonstrated its supremacy, and developments and extensions proceeded apace. Hitherto the average horse-power per vehicle had been 25, but it was ascertained that street transportation could be employed for purposes beyond the mere carriage of passengers. The result of this widening of the sphere of application, which enabled merchandise to be carried through the streets, introduced heavier vehicles, which in turn demanded more powerful motors. The outcome was the gradual increase of the horse-power per vehicle, until motors of 65 horse-power came to be recognised as the general standard. Whereas the 25 horse-power cars of 1895 had carried only a single motor, the heavy inter-urban vehicles are now fitted with four motors, while those moving within the cities are equipped with two motors. At the present moment the aggregate mileage of tramways in the States is approximately 65,000, and the average yearly increase is being maintained. Moreover, Canada, realising the advantages and possibilities of this system of intercommunication between cities and suburbs, is feverishly extending its facilities of this description.

Possibly one of the greatest transitions of this character was that carried out in London. The traffic of the metropolis is heavier than in any other city of the world, and the necessity to provide breathing space for the millions of toilers within and immediately surrounding the historic square mile comprising the actual City itself, demanded a means of conveyance superior to the horse-drawn tram. The essential conditions which had to be met were cheap fares and rapid travel. At the time the issue reached a critical stage, nothing superior to electric propulsion was available. By the early months of 1910 the tramway system of the metropolis, operated by the London County Council, comprised 132 miles of working lines, of which 112 miles were electrically operated. The far-reaching influence which the conversion to electricity exercised upon the public is revealed from the fact that whereas a round 314,000,000 people were carried by this means during the fiscal year of 1909, the number had risen to over 450,000,000 a year later.

The success of electric propulsion upon the street railways naturally served to turn the attention of engineers and inventors to the feasibility of adapting it to trunk railway working in place of steam. There were several factors which influenced such a conversion, especially in crowded areas possessing underground, surface, and overhead railways serving the outlying districts. Smoke and steam contributed to the general unhealthiness of the cities, owing to the contamination of the atmosphere, while in cases where the stations or stopping places were spaced somewhat closely together locomotion was rather slow. While the station question would remain, even if electricity were adopted, it was maintained that, owing to the more rapid acceleration and deceleration features of the electric system, it would be possible to attain higher running speeds between stopping points, which in turn would enable given journeys to be completed in shorter time than was practicable with steam working, and owing to this factor it would be possible to run the trains over a given road at more frequent intervals.

At first the new development was not regarded seriously for what may be termed as main-line working. It was regarded essentially from the aspect of improving intra-mural movement and as a competitor or alternative to the tramways. In this application Great Britain became a pioneer by introducing a new type of railway to the world—the tube. The first line of this character was the City and South London Railway, which was bored through the London clay and sand for a distance of 3½ miles, from Stockwell to the Monument. It was opened in 1890, and attracted world-wide attention, because each road —the up and the down respectively—was laid in its own circular tunnel, interconnection being provided at certain stations. The tunnels were driven by means of the Greathead shield at depths varying from 50 to 80 feet, the excavators working upon the face in a compressed atmosphere. By this system of construction it was rendered possible to bore beneath the River Thames, the pressure within the shield being adequate to keep back the water and treacherous river-bed. The continuous burrow thus formed was lined with segments of iron bolted together, the internal diameter of the tunnel being 10 feet 2 inches. Owing to each train being confined to its particular tunnel, greatest safety was assured, the trains working in the manner of shuttles.

The initial experiment having proved successful, other and more ambitious railways of a similar character were taken in hand, with the result that the metropolis is now honeycombed with tube railways. By this means it has been possible to establish cheap and rapid communication between the City and suburbs which formerly were somewhat far apart, if not in miles, at least in travelling time. The convenience of the public was further improved by the provision of interchanging facilities at various points, the outcome being that it is possible to travel from one part of the metropolis to another by tube. Similar systems were subsequently laid down in other cities, such as New York, Paris, and Buda-Pesth ; but in their construction the Greathead shield was not employed, partly owing to the character of the soil which had to be penetrated, and the shallow type of railway was favoured—that is, placing the lines only a few feet below the street level as in the case of the Metropolitan Railway of London. In these instances, construction was carried out from the street, which was opened up to enable the necessary excavations to be made. The tunnel was then roofed in, the steel covering being supported by pillars, and on this metal roof the road was remade.

While the construction of these special electric railways was under way the application of electric traction to the main lines was taken in hand. At first the efforts were far from pretentious, electricity being introduced to ameliorate conditions provoked by steam working, or to enable heavier, longer, and more trains per hour to be handled. One of the first conversions of this character was completed in 1895, when the tunnel at Baltimore (U.S.A.), which is set upon a steep gradient, and in ascending which the steam-hauled trains were often forced to a stop owing to the weight of the train being beyond the power of the locomotive, was electrified.

In this instance the superiority of electric working was so pronounced that the conversion of other tunnels was taken in hand, notably the Cascade tunnel upon the Great Northern Railway of America and the St. Clair tunnel of the Canadian Grand Trunk Railway. From such an unpretentious beginning the electrical engineer advanced to greater fields. In 1903 came the electrical operation of all trains passing in and out of the New York City terminus of the New York Central Railway, followed later by similar working of the Pennsylvania Railway in the same city. In the latter instance some huge locomotives were introduced, the total energy, working in tandem, being 4,000 horse-power. Each locomotive is equipped with a 2,000 horse-power motor, the power from which is transmitted to four coupled driving wheels 72 inches in diameter. The engine measures 65 feet in length, and weighs 157 tons ready for the road. Recently the New York Central has acquired six new electric locomotives of even greater power, having been designed to haul a train weighing 1,200 tons upon a level straight line at a sustained speed of sixty miles per hour.

While America was forging ahead in this field, European electrical engineers were every whit as busy. The question of adopting electric working upon the great Alpine tunnels was discussed, and was first reduced to practice in the case of the Simplon railway. Two locomotives, each developing 1,000 horse-power, were run side by side with steam locomotives of equal power. From a comparison of the results presented by steam and electric working the authorities were able to make their decision, which was given in favour of the new system of train hauling.

One interesting feature of the locomotive was revealed in this instance. Although both types developed approximately identical horse-power, the weight of the steam engine was more than twice that of its rival, the former scaling 110 tons, while the latter weighed only 62 tons, of which 42 tons was imposed upon the driving wheels. When the Loetschberg tunnel was completed electric working was adopted, and for this line powerful engines developing 2,000 horse-power were built. Since then other European railways have been won over to electric traction for their main lines, one of the most important enterprises of this character being the electrification of the great Swedish main line between Kiruna and Riksgransen.

In all these instances, however, the length of road which has been converted to electric working is comparatively short. But a decided impetus to electricity was imparted in 1913 by the decision of the Chicago, Milwaukee and St. Paul Railway, a recent American transcontinental line, to electrify the whole of its mountain section. The negotiation of the Rockies has ever constituted a thorny problem to the railway builders, owing to the extreme difficulties which have been encountered in maintaining grades sufficiently easy for economical working; while, moreover, the fuel for the locomotives, the consumption of which is somewhat heavy, has to be hauled over long distances. But among the mountains there are waterfalls innumerable which may be harnessed, and which may be induced to furnish an enormous volume of energy. Under these circumstances the railway directors decided to electrify the section, and the plans called for the conversion of 440 miles of line. The first stretch has been completed and is now in operation, the locomotives for the service being monsters weighing 260 tons and developing 3,000 horse-power.

The feature of this undertaking is the regenerative system which is employed. In ascending the long gradient electric current is consumed, but after the summit has been gained there is an equally long descent, during which it is not necessary to call upon the locomotive for an ounce of effort. Coasting is possible, the train being kept under control by the brakes. But the long descent has been put to useful purpose. The motors, which drive the locomotive during the long climb, are caused to act as generators during the down-hill run, and the current thus generated is returned to the power station.

So far as Great Britain is concerned, main-line electrification has not been adopted in connection with our railways upon an ambitious scale. The North-Eastern led the way by electrifying its suburban line, which feeds the teeming districts along the north bank of the Tyne. Other railways followed suit where the conditions were somewhat analogous, such as the Brighton Railway, which took in hand the electrification of its southern suburban network, which is now being carried through to completion. Similarly the London and South-Western Railway has commenced the electrification of its outlying network. In all these instances electrification has been forced upon the railways in the interests of self-preservation. The electric tramways came, and, owing to the superior speeds thereby offered, they filched the greater part of the traffic from the steam railways serving the selfsame areas. The railways are retaliating by electrifying their competitive lines. By the attraction of a frequent high-speed service combined with low fares, they have been able to hit the electric tramways in turn, and have either regained the greater part or the whole of their lost traffic.

One of the most beneficial electrification schemes from the public point of view was the conversion of the first underground railways of London. These were threatened with virtual extinction by the electric tramway systems. The services were slow, ventilation was indifferent, and the rolling stock was so antiquated as to be regarded as prehistoric. But an American, who had achieved great things in his native land with electric tramways, came to London. This was Charles T. Yerkes. He saw that if only the moribund system were converted to the new order of things it would be able to regain its long-lost prestige, and become a powerful factor in the handling of London's busy traffic. He secured sufficient power to carry his ideas into effect, and the whole of the lines were electrified. The bold move was fully justified, and the anticipations of the promoter of the scheme have been more than fulfilled. The system has been transformed from a derelict into the most important and busiest railway artery in the metropolis. To-day it carries more passengers than any other comparative undertaking, and has a finer and faster service.

Electrification completely vindicated itself in this instance. Not only were higher speeds achieved than had ever been known in the steam days, but it became possible to improve the frequency of the service so much as to enable fifty trains per hour to be run, and at times of pressure this frequency can be increased. No other city in the world is able to excel the facilities of London in this direction, the Underground Railways being generally considered to offer one of the most brilliant illustrations of electric working.

But as the electrically driven tramway drove the horse-drawn vehicle from the streets, so is the former now being seriously threatened. The outstanding drawback of any system of locomotion depending upon its own thoroughfare, as represented by a pair of rails, is the absolute indispensability of keeping to that highway. There is an utter lack of flexibility. If a car breaks down the interruption not only affects the disabled vehicle, but it brings every following car to inactivity. Traffic cannot be resumed until the accident has been repaired or the lame duck has been towed away. A similar state of affairs is precipitated if anything befalls the track or the conductor, although in the case of an overhead system the breakdown can generally be repaired within a short time.

The condemnation of the vehicle to the pair of metals was responsible for the perfection of another trend of thought and its reduction to practical application. This manifestation of ingenuity has produced what may be termed as a hybrid—one with the salient characteristics of the omnibus and the tramway ingeniously combined. In this instance the vehicle, which follows the familiar lines of the omnibus in its design and which may be adapted for carrying both inside and outside passengers, or the former only, is equipped with the trolley pole.

The overhead conductor is strung in the usual manner, but the trolley pole is of sufficient length to command the radius of half the road, or in the case of a narrow road, when the conductor is placed to one side of the street, to reach across the full width of the thoroughfare. The flexibility of this trolley pole and its freedom of movement enables the car to travel at the full reach of the pole, and with as perfect contact with the conductor as when travelling immediately beneath the overhead wires. Thus the trolley-bus, as it is called, has full command of the width of the street, is able to thread other traffic, and does not monopolise any part of the highway as is the case when a pair of rails is laid down.

Thus the new vehicle has a mobility which is denied its tram rival. It is even attempting to threaten the motor-bus. As in the case of the latter, a breakdown does not affect the whole of the system, but merely the vehicle which has become incapacitated. Its trolley pole can be removed from the conductor, allowing other cars to pass, while the derelict may be towed into the sanctuary of a quiet street to be repaired, or may be hauled back to the garage to be overhauled. This is the great advantage of the trolley-bus over the tram-car, and it serves to bring electric traction for public vehicles more into line with the petrol motor-bus which has played sad havoc with the prosperity of the tramway. But, nevertheless, the trolley-bus cannot compete with the motor-bus, because the latter can go anywhere so long as there is a passable road surface to provide a grip for its wheels. If one street is closed it can swing to the right or left and follow a parallel thoroughfare. But the trolley-bus, in common with its electric contemporary, is condemned to the highway along which its overhead conductor is strung. Consequently, all things considered, the trolley-bus does not represent a decisive factor in intra-mural communication, since it possesses at least one of the worst disadvantages of the electric tram-car. Its true province would seem to be in rural districts, or as a means of locomotion in quiet residential areas of limited traffic possibilities, acting in the capacity of a feeder to a tramway system. It is cheaper than the latter to instal, inasmuch as the rails do not enter into the question.

The fact that the trolley-bus is not regarded as a serious contribution to the problem of rapid and cheap inter-urban and intra-mural locomotion is offered by the United States. In that country, which is admittedly exceedingly enterprising in matters pertaining to transportation, and where authority offers little interference, the hybrid method is not regarded seriously. It lacks the carrying capacity of the tram-car, and is not so speedy. Moreover, it cannot operate upon the multiple unit system, which has now come extensively into favour.

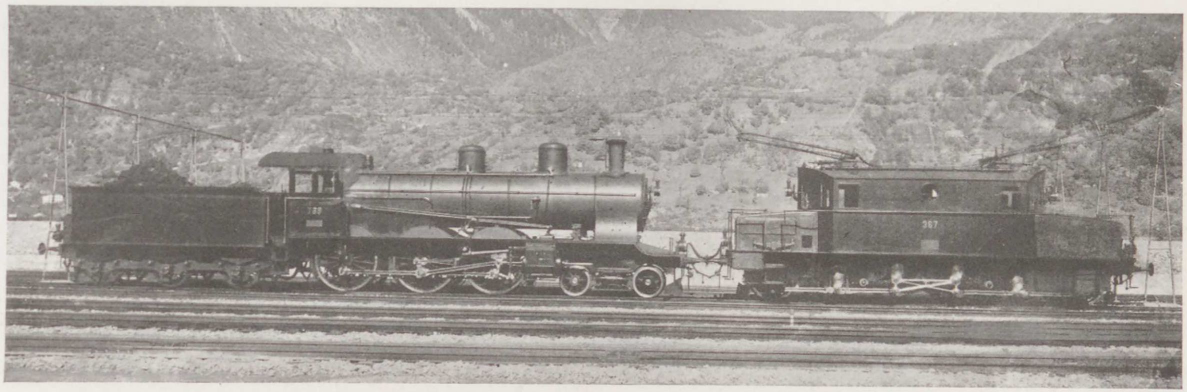
The trolley-bus would appear to be in danger of becoming superseded before it has become established. Commendable efforts are being made to adapt ordinary vehicles to electric propulsion, and during the past two or three years decided progress has been recorded. Davidson's electric battery propelled car has never been forgotten. It has always been realised that if the accumulators could be improved so as to give a greater radius of action upon a single charge, and that with a reduction in the weight, dimensions and bulk of the accumulators themselves, then the electric vehicle might come into its own and be able to compete with other forms of mechanical traction. The first experiment which was made in these islands in this direction proved a failure, since the drawbacks were quite as pronounced as in Davidson's trial car. Moreover, the difficulty and expense of recharging the batteries were too formidable to be overcome. The number of stations available for this essential purpose were somewhat limited, while they extended no inducements for this development. Electricity has failed to make the progress in these islands which is to be recorded in other countries, mainly owing to grandmotherly legislation which was introduced at a time of panic and ignorance when the new science was young, thereby virtually strangling it before it had the opportunity to assert the multifarious benefits which it is able to bestow upon the community.

The latest revival in this field is making greater headway. The public have become enlightened and educated in matters pertaining to electricity. The accumulator has been improved out of recognition, while now it is possible for a vehicle to complete 100 miles or more, according to its designed duty, upon a single battery charge. The opportunities to recharge the batteries have also undergone considerable extension. Electric lighting is now used on every side, and where electric lighting is in service it is not a difficult matter to complete arrangements for recharging the batteries when necessary and during the periods when the vehicle is not required. The public companies supplying electricity are also more amenable, having realised that the electric car, whether it be used in the interests of pleasure or commerce, is destined to a great future. Now they are prepared to recharge the batteries at a reasonable figure, and this cost tends to be reduced. An electric generating station shows its greatest profit when it is able to keep up to its full output throughout the round twenty-four hours. At present there are times during the day and night when the demand falls below maximum supply. These are the periods when the current could be profitably switched in to charge accumulators. Possibly in the near future, as the electric vehicle increases in popularity, the dimensions, weight, and capacities of the storage batteries will become standardised. In such an event it would be possible for electric charging stations to acquire a sufficiency of batteries and to keep them charged. A customer, whose battery was running down, would drive up, withdraw his exhausted accumulator, and hand it over in exchange for one which was charged. The batteries being equal value, neither would lose over the exchange. The customer would merely pay for so much electric current as represented by that stored in the battery, reconnect up, and drive away. If the number of such stations were sufficient, it would be possible to embark upon long tours without the slightest hesitation, the changing of accumulators at successive stations merely being equivalent to the purchase of supplies of fuel. The accumulators would correspond to the petrol cans which are readily exchanged at every garage to-day, although, of course, the capital outlay would be decidedly heavier. But a battery, if properly handled, and especially if of the character which has been perfected by Edison, will stand very rough handling and last for years.

The advantages of the electric vehicle are so pronounced as to impress everyone. It offers smoother running; vibration is absent; control is easier—there is only a single lever; construction is simpler and more durable; it is cheaper to maintain—intricate gears

THE FIRST ELECTRIC RAILWAY

This line was laid down at an Exhibition in 1879, and created a great sensation because of its novelty.



STEAM SUPERSEDED BY ELECTRICITY

The steam locomotive of the Simplon Tunnel Railway standing beside the electric locomotive which took its place. The former is twice the weight of the latter, but by no means so speedy.

and other complications are eliminated; it is cleaner to handle, and, when standing still, it does not eat up fuel, the current being switched off during such periods of inactivity. It possesses all the mobility of the petrol-driven car with none of its shortcomings, and does not present any troubles which might be characterised as peculiar to itself, because there is practically nothing to get out of order. The cost of petrol is rising rapidly, whereas the cost of electric current tends to decrease, especially in applications to power, under which category battery charging is rated. In these islands the price of current is governed by the fluctuations in the price of fuel—gas or steam being the agents which are employed almost exclusively for the generation of electricity. This influence is experienced in every country where similar conditions prevail, but does not arise where water-power furnishes the means of generating the current.

It is significant to remark the vast strides which the electrically driven vehicle is making, especially in industrial circles, both in the form of light delivery vans and heavy trucks. In some instances it has even ousted its petrol-driven rival, the running expenses, as a result of comparative data, being overwhelmingly in its favour. Furthermore, the use of batteries is not being confined to free road vehicles. Omnibuses and tram-cars operating upon short links, such as transverse feeders to the main networks of communication, have proved highly successful. In the case of the tramways they dispense with the necessity of installing costly overhead or underground conductors. Accumulators have even made their reappearance upon the railways, especially in Germany, for service through crowded areas where the length of line is comparatively short. These battery-driven trains have proved themselves capable of meeting all requirements, and invariably complete a day's work upon a single charge, and are recharged during the night, when the traffic is at its lowest ebb. Accumulator-driven barges and other small craft, particularly those plying upon canals and inland waterways, have even made their appearance, and having established their value, are multiplying rapidly.

Despite the fact that electricity, as a propelling force, has been in vogue for a quarter of a century, it is only now emphasising its far-reaching influences. Progress has been rapid since the initial difficulties were overcome, and by the acquisition of knowledge. It must be remembered that twenty-five years ago practically nothing was known about electricity in its application to science. The electrical engineer was unknown; he is a product of the contemporary generation. If the progress in matters pertaining to electric traction which has been recorded during the past twenty years is maintained, there is every indication that electricity will become supreme as the driving force in all realms of transportation and mechanical locomotion long before the wane of the present century.

CHAPTER VI

The Westinghouse Brake and its Effect on Travel

ONE afternoon, away back in 1866, a young man boarded the New York Central train at Troy in the State of New York, bound for his home at Schenectady, twelve miles distant. He was only a young man of twenty, and but a few months before had returned from the turbulent South, which had been riven and torn by the Civil War.

Even in those days the journey between the two towns was only a matter of twenty minutes or so, but on this afternoon about two and a half hours were occupied in the run. The train was brought to a standstill at a lonely point and forced into idleness for two hours. Two goods trains had disputed the right of way with the inevitable result—a tangled heap of debris scattered over the railway, completely obstructing traffic.

In common with the other passengers, the young man fretted and fumed at the delay, but the loss of time and the inconvenience did not affect him so seriously as it did several other fellow travellers. The young man whiled away his time as best he could under the circumstances, but as he waited an idea which had suddenly occurred to him kept running through his mind with uncanny persistence and frequency.

These trains had probably come into collision through their respective drivers being deprived of the ways and means of pulling them up sharply when danger threatened. Now, if they had been equipped with a system of brakes, capable of acting upon every wheel in each train, the accident might have been avoided.

This was the trend of thought which haunted the young traveller. The longer he pondered over the idea the more firmly convinced did he become that such an arrangement might be perfected.

The young man was an engineer, and, indeed, had been attached for some months to the engineer corps of the Navy during the Civil War. His father was a successful manufacturer of agricultural machinery, and his works at Schenectady were well known and excellently equipped. The son had inherited the paternal taste for mechanics, and during his boyhood had been encouraged to spend his spare time among the machine tools and in the drawing office attached to his father's shops. After leaving the Services he had entered the Union College through the examinations at which he had passed with flying colours. He was also conversant somewhat with railway problems. In the previous year he had introduced a device for expeditiously replacing derailed railway vehicles upon the metals, and at that moment was occupied with another device to facilitate a certain phase of railway working.

But now the brake idea became his obsession, and he resolved, before he reached home that afternoon, to work out a system which would conduce to greater safety in railway travel. He was familiar with the braking systems which then obtained, and all of which were of the most primitive design, unreliable, and consequently had only received indifferent attention.

His first idea was to fit brake levers to each vehicle in such a manner that when the brake on the locomotive was applied it would cause the brakes on each successive vehicle to come into action in turn through the tendency of the latter to crowd upon the locomotive. He even essayed to build an apparatus upon these lines, but was compelled to abandon the project. The idea was too crude, while it also suffered from the lack of novelty. Several other minds had previously conceived such a system only to discover its impracticability.

Some time later the young engineer happened to be in Chicago. While there he was invited by the superintendent of the Chicago, Burlington, and Quincy Railway to inspect a new train, the "Aurora Accommodation" as it was officially styled, which had just been brought into service, and of which the railway was proud. The train aroused the young visitor's enthusiastic interest because it was fitted with a new type of brake which acted on all wheels and which was brought into action by the locomotive. This brake was a topic of considerable discussion in railway circles, and its first practical application upon such a scale was being awaited with intense expectation.

The young man was extremely fortunate that day, because at the time of his visit the inventor of the new brake, Mr. Ambler, happened to be on the train completing the final tuning-up. Observing the young engineer's interest in the invention, Mr. Ambler offered to explain and to demonstrate the system to him.

This brake belonged to what is known as the chain type. From one end of the train to the other extended a long chain, passing beneath the carriages, and to which all the levers of the brakes upon each carriage were connected. But the system of application was novel, although in the light of contemporary knowledge we should describe it as being freakish. On the locomotive was mounted a windlass, to which one end of the train chain was attached. This windlass was provided with a grooved wheel. When the brake was to be applied this grooved wheel was moved until it came into contact with the flange of the driving-wheel of the locomotive. Through pressing against the latter a friction drive was obtained which rotated the windlass and thus wound in the chain. As the latter was drawn taut the brake levers were pulled forward and the brake-blocks were thus brought to bear upon the wheels of each carriage, and almost simultaneously.

The inventor was intensely proud of his novel idea, and was thoroughly convinced of its efficiency and reliability. When he had concluded his explanation the young engineer diffidently explained that he too had been thinking out an idea for a railway brake—in fact, at that very moment was engaged in building a model. At this the inventor turned to the young man, and in a patronising air remarked:

" Mr. Westinghouse, I admire your intentions, but really you are wasting your time."

" How so?"

" Well, you can see for yourself that I have conceived the only really feasible braking system, and, of course, as you may well imagine, I have fully protected myself with patents."

Young George Westinghouse apparently accepted the advice and the opinion that his labours were in vain, but inwardly he commented to himself that he would strive harder than ever to build a brake superior to that evolved by Mr. Ambler, the shortcomings of which were only too obvious. The moving windlass struck him as being particularly primitive and likely to precipitate considerable trouble.

Upon his return home he attacked the problem in greater earnest. In his own mind he was convinced that George Stephenson, the father of the locomotive, had struck the correct line of development when he brought out his steam-applied brake controlled from the locomotive, and he set out to elaborate and to expand this idea. But he speedily appreciated the limitations attending the utilisation of steam. A braking system, such as he evolved, proved perfectly satisfactory when only four or five carriages constituted the train; but, as a matter of fact, even then the latter was growing, from ten to twelve or more carriages being attached to a single locomotive. Steam, therefore, in its employment as he then contemplated, was forced to go the way of the chain-operated method.

One day a couple of lady canvassers, who were seeking subscriptions for a monthly magazine, entered the works of Mr. Westinghouse at Schenectady. The young engineer was busily engaged, but he was forced to suspend operations and to listen to their seductive conversation. To escape their pressing persuasions he made the best move he could have done under the circumstances. He became a victim, and parted with his money for the regular supply of the paper through the post. When they had disappeared all thoughts of the magazine vanished from his mind.

In due course the periodical arrived, and was perused at an idle moment. Scanning the pages hurriedly, the attention of young George Westinghouse, whose thoughts ever ran into channels pertaining to his craft, became riveted upon the story which formed the main feature of the magazine. It described the construction of the tunnel through Mont Cenis, which was then in active progress. In his leisure he read the article carefully, only to have his thoughts become centred upon one incident in the story. This was the actuation of the drills, boring and cutting into the solid rock-face at a distance of 3,000 feet from the portal, which was the length to which the tunnel had been driven through the mountain at the time the article was written. These drills depended upon compressed air, which was conveyed through a continuous length of pipe.

In a flash the secret of the railway brake burst upon him. If compressed air could be carried through a pipe to drive machinery 3,000 feet away, surely it could be carried through a pipe equal to the length of the longest train then in service, and could be induced to actuate the brake rod attached to every axle throughout the train. Compressed air would do for him what could not be done with steam.

Excited at this sudden thought, he instantly devoted his energies towards the designing of a brake system for operation with compressed air. At the earliest possible moment he lodged the necessary preliminary document, or caveat, with the United States Patent Office to protect his idea. That was in 1867.

Shortly afterwards young Westinghouse moved from Schenectady to Pittsburg. Here he met Mr. Ralph Baggaley, to whom he explained his invention. He succeeded in enlisting the sympathy of the latter to such good purpose that Mr. Baggaley undertook to defray the cost of building a full-sized and complete installation wherewith to demonstrate the possibilities of the brake to railway officials. The utilisation of compressed air in this connection proved a decided novelty, and Westinghouse scored a distinct success over any likely contemporary workers by lodging his full patent.

But the construction of the demonstration apparatus proved a tedious task. It could not be fitted to a train straight away, because thereby it would be impossible to point out and to explain the individual features and details of the system. The braking method had to be built upon a full-sized scale, and had to be laid out to a sufficient length, as if it were intended for a complete train. It comprised a pump which drove the necessary air into a main reservoir or tank, and under pressure to actuate the brake fitted to the locomotive wheels. This was connected up to an array of cylinders corresponding to those which would be placed beneath the following carriages. The installation was completed to the smallest detail, and so many months were occupied in the work that the year 1868 was well advanced before it was ready for official inspection.

An invitation was then given to the Pennsylvania and what was known as the Panhandle railways to inspect and to test a new brake system for railway trains, which had been perfected and which was operating upon quite a novel principle. The offers were accepted and the officials, representing the systems, were so impressed that the superintendent of the Panhandle Railway requested young Westinghouse to remove the apparatus from his shop and to instal it upon one of their regular trains, which comprised a locomotive and four coaches.

Needless to say, such an opportunity to prove the value of the brake under actual service conditions was not missed, but the subsequent trials proved far more impressive and complete than even the sanguine inventor had anticipated. Upon the very first run, what might otherwise have proved a disaster was avoided through the brake. The train was emerging from the tunnel in Pittsburg, when the driver caught sight of a horse and wagon standing upon the track at the crossing. The driver instantly jammed on the new brake, and the train pulled up dead some yards away from the obstacle. As may be supposed, the driver, as well as the other officials and the inventor, who were aboard the train, were decisively affected by the narrow escape and the striking efficiency of the new brake. From that moment there was never the slightest doubt but that the brake would come into universal application upon the railways. It had emphatically demonstrated the part it could play in securing greater safety in railway travel.

This incident happened to occur at the very moment when there was a public and official demand for greater safety in railway travel. But the inventor speedily recognised one salient factor which could only ensure the financial success of his idea. The railway brake would have to be universal. If one railway adopted this, and another that, system, hopeless confusion would ensue, and the invention would defeat its own object. Unless there were uniformity, standardisation, and interchangeability, it would render railway intercommunication and the movement of the vehicles of one system over the lines of another impossible.

Thereupon it was decided to place the manufacturing side of the invention upon a solid foundation, and to this end the Westinghouse Air Brake Company was founded in 1869, with works at Pittsburg, at which city they remain to this day. Indeed, around this humble, unpretentious first shop, the vast and varied organisation of the Westinghouse business has developed and flourished.

Moreover, the details of the apparatus were standardised without delay, and the broad features then outlined still prevail. They comprised an air-pump, mounted upon the locomotive and actuated by the steam generated in the latter. The engine equipment also included a main reservoir into which the air was forced until the desired pressure was obtained. The locomotive equipment was completed by a valve mechanism operated by the driver to apply and to release the brakes. The equipment for the carriages was also laid down, together with the connections between the locomotive and the attached vehicles, the piping, when joined together, forming a continuous line from the locomotive to the last vehicle, with a branch pipe leading to each cylinder mounted beneath each car.

In designing the lay-out of the equipment it was necessary to devote attention to the facilities for cutting off, or extending, the length of the main pipe-line, according to the detachment or attachment of vehicles. This necessitated a flexible coupling between the vehicles and capable of instant severance or connection. Moreover, each flexible connection required a valve. When two cars were coupled up this valve automatically opened, but when the connection was broken the valve automatically closed, with the result that the air-pipe was always kept closed, thereby preventing the escape of the compressed air when once it had been introduced into the brake-pipe.

The news of the unexpected and completely convincing trial upon the Panhandle system rapidly spread through the American railway world. The eyes of all the various managers and superintendents became focused upon the new idea, which was something never seen before, and which, it was universally agreed, exceeded all previous attempts in this field. The Pennsylvania Railway approached the inventor and requested him to fit the brake to a train of six coaches, which they placed at his disposal for the purpose. This company had been attracted to a chain brake, but it had not proved completely satisfactory for the very reasons which Westinghouse had determined many months before.

This experimental train was hauled to the heavy section of the system which runs through the Allegheny mountains. Here it was submitted to the most exacting tests which could be conceived. The train was driven up and down the slopes, and at frequent intervals the driver was ordered to pull up. Never once did the brakes fail, even upon the steepest sections; and the short distance in which the train could be brought from full speed to a standstill astonished those who were on board.

The Pennsylvania Railway then sent a longer train of ten vehicles to Pittsburg to be fitted out with brakes, with the intimation that this train was subsequently to proceed to Philadelphia in order to enable demonstrations and trials to be carried out to convince the directors of the railway that a successful braking system for trains had been evolved and brought to practical perfection.

These trials were of far-reaching importance to the inventor. He had interviewed many of the most prominent railwaymen in the country, and had endeavoured to persuade them to embrace his idea before the sensational test upon the Panhandle Railway, but they had manifested only a lukewarm interest in the scheme. Now they were invited by the directors of the Pennsylvania Railway to come to Philadelphia and to judge of its suitability upon the spot with a typical train. Needless to say, full avail was taken of this invitation, and among those whom it attracted was the general superintendent of the Chicago and North-Western Railway. He hurried to Philadelphia, saw, and was convinced to such a decisive degree that he asked the Philadelphia Company to send a train fitted with this brake to Chicago, when he would arrange trials to which the leading railway officials of the Middle West would be invited, while the Press would also be persuaded to take up the matter.

The directors of the Philadelphia Railway fell in with this suggestion, and the braking apparatus was transferred to a brand new train of six coaches and a locomotive for the purpose. It was run to Chicago and submitted to tests of every conceivable character upon the Chicago and North-Western Railway for the enlightenment of the railway officials of the Middle West. The train subsequently was moved on to another city for further demonstrations, and then returned to Pittsburg.

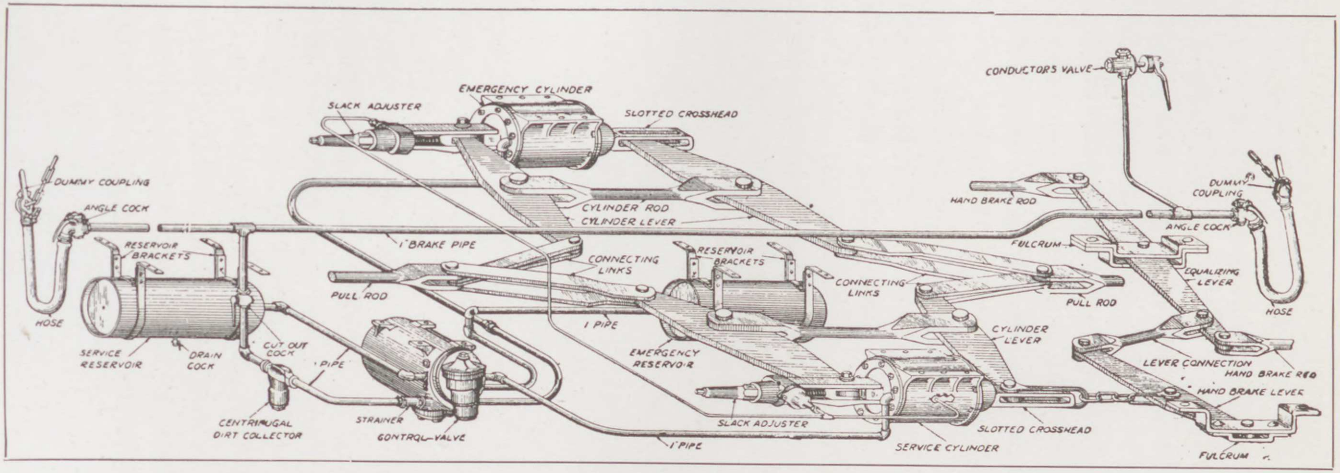
Orders now began to roll in, especially from the new transcontinental railway across the States to the Pacific seaboard, which had been recently completed, and for which rolling stock was being purchased. The interchangeability and standardisation of the brake played a prominent part in securing its widespread adoption, this being one of its outstanding features from the commercial point of view.

Yet there was one, and a pronounced, objection to this brake, which Westinghouse speedily realised. It was not automatic in its action. In the event of a train breaking in twain—which was a very common occurrence in those days—the detached portion became uncontrollable. On the pioneer lines of the United States the grades, especially through mountainous districts, were very heavy, and trains breaking in two during the climbs led to terrible disasters. There was another defect. A relatively long period was occupied in bringing the full retarding effect into force upon a train, while much more time was required to release the brakes.

But the lack of control over a breakaway was the greatest danger, which demanded instant attention. Thereupon Mr. Westinghouse once more took up the problem, his goal being the perfection of an automatic system. In consummating this end, in which he was strikingly successful, he was able to profit from another invention which he had evolved, and which had been adopted upon trains. This was a signalling system, comprising a pipe extending beneath the carriages throughout the length of the train to the locomotive, on which was mounted a small cylinder carrying a whistle. If a valve connected to this pipe were opened at any point of the train, the whistle was blown, thereby attracting the driver's attention to the fact that something was amiss. The success of this signalling device depended essentially upon a very sensitive valve controlling the passage of air from the reservoir upon the engine to the train pipe, and this always came into action whenever any air was permitted to escape from the train pipe through the opening of a signalling valve, say, by the guard or passenger. It was the movement of the delicate valve on the reservoir which brought the whistle into play.

As a result of several interesting experiments, from which it was ascertained that waves of air travelled through the signalling pipe at the same velocity as sound, namely 1,100 feet per second, Mr. Westinghouse conceived a brilliant idea. He decided to introduce a valve combination into the braking system, which was still further improved by adding an auxiliary reservoir to the original equipment beneath each carriage. The valve system was introduced between the brake pipe, brake cylinder, and the auxiliary reservoir, the inventor maintaining that if the wave of air, such as was sent through the signalling pipe and which brought the whistle into play, could be induced to operate the valve device which he embodied in the brake system, then almost instantaneous braking would be achieved. As events proved, his reasoning was strikingly sound.

It must be explained that in the original Westinghouse system, which was described as the "non-automatic" or "straight-air" brake, the retarding effect upon the train was produced by the driver moving a lever or valve, which allowed air to pass from the reservoir mounted upon the locomotive into the train pipe. This increased air pressure, travelling through the pipe, entered each cylinder mounted beneath the carriages successively and forced outwards a piston mounted in the cylinder. To the outer end of the piston the brake lever was attached, with the result that as the piston moved outwards, the brake blocks were applied to the tread of the wheels. It was supposed that all the pistons of the carriage brake cylinders moved simultaneously and set the brakes according to the force exerted, and which varied, by the volume of air admitted into the train pipe. But as a result of the subsequent searching tests and trials, it was discovered that this supposition was incorrect. When the driver desired to release the brakes he moved the valve of the reservoir upon the locomotive so as to cut off all communication with the train pipe. Then he moved another valve which opened the train brake pipe to the air, thereby permitting the compressed air within



THE "WESTINGHOUSE" BRAKE

Details of the equipment attached beneath a modern heavy passenger coach to ensure safety in high-speed railway travel.

the pipe to escape until the pressure within the pipe became the same as that of the outer atmosphere —namely, 14 pounds per square inch. As the compressed air escaped, the pistons of the brake cylinders moved inwards, so that the brake-blocks were drawn clear, leaving the wheels free.

While the foregoing system is delightfully simple, that of the automatic quick-acting brake is far more so, although the means whereby the desired ends are achieved appear to be somewhat elaborate, if not intricate. The valve mechanism, placed between the brake pipe, brake cylinder, and the auxiliary reservoir, fulfils the following function. When compressed air is admitted into the train pipe, the valve mechanism acts in such a manner that the compressed air is allowed to pass into the auxiliary reservoir. Thus the two are open to one another, so that the air pressure in the train pipe and the reservoir is identical. At the same time the valve mechanism opens a second passage from the cylinder, in which the piston connected to the brake-block system moves to and fro, to the outer air, so that the air within the brake cylinder is not under pressure. This is the position when the brakes are "off," as when the train is travelling.

To apply the brakes the driver moves a lever, which causes a certain proportion of the compressed air within the train pipe to escape into the outer atmosphere. This action causes the valve mechanism to close the connection between the train pipe and the auxiliary reservoir carrying air under pressure, so that the pressure of air within the auxiliary reservoir is now higher than that obtaining in the train pipe. At the same time the outlet from the brake cylinder to the open air is closed. Thus two definite functions have been carried out by the valve mechanism. Now a third movement occurs. This is the opening of the passage between the auxiliary reservoir and the cylinder carrying the brake piston. As the air within the auxiliary reservoir is compressed, while that within the brake cylinder is at the normal atmospheric pressure of 14 pounds per square inch, naturally the air rushes from the auxiliary reservoir into the brake cylinder. In so doing the piston in the brake cylinder is moved outwards and actuates the braking mechanism, causing the brake-blocks to come into contact with the wheels. When the driver desires to release the brakes all that is necessary is to admit compressed air into the train pipe, which opens the brake cylinder to the air, thereby permitting the compressed air in the latter to escape and the piston to move inwards and to remove the brakes from the wheels. At the same time, the passage between the brake cylinder and the auxiliary reservoir is closed, while that between the auxiliary reservoir and the train pipe is opened. Owing to the air-control mechanism performing three definite and distinctive functions, it is known as the " triple valve."

It will be seen that this brake is absolutely automatic in its action. When it was first submitted to test, its superiority over the former or " straight-air brake " system was so pronounced as to force the original invention into the background. When a train breaks in half, the rupture of the train pipe, enabling the compressed air within the latter to escape, brings the auxiliary reservoir and the brake cylinder into communication, closes the air outlet in the latter, and also the passage between the auxiliary reservoir and the train pipe. Consequently, the volume of compressed air remaining in the auxiliary reservoir can flow only into the brake cylinder, forcing out the piston and bringing the brake mechanism into play. The cycle of operations is exactly identical with that brought about by the deliberate action of the driver when he wishes to slow down.

Thus it was seen that the runaway portion of a train speedily came to a standstill, entirely through the automatic action of the brakes and without the guard being called upon to do anything. Moreover, the brakes could not be taken off the severed portion until the pressure within the train pipe was restored by recoupling-up or through the opening of an emergency valve, which imposed a definite and deliberate action upon the part of the guard.

The achievements accomplished by the Westinghouse pneumatic brake reached Britain, and in the early 'seventies the invention was placed upon the British market. But the introduction of an innovation here was not straight sailing, because other creative minds had been attracted to the issue. The fact that the British railways were fully alive to the merits of a continuous brake was brought home by a series of competitive trials held in 1875 and 1878 respectively. The first were held at Newark on the Midland Railway, in which the Westinghouse automatic brake, although of an early type, achieved the best performance: a train of fifteen carriages, representing about 150 tons, being brought to a standstill when travelling at 52 miles per hour—the highest speed which could be attained—in 18 seconds. In the later trials—1878—which were probably the most searching which ever have been carried out, and which yielded technical data of inestimable significance, an experimental vehicle equipped therewith was stopped when travelling at 52 miles an hour in $11\frac{1}{2}$ seconds.

In America the Pennsylvania Railway also submitted the automatic system to an exacting demonstration. A train of fifty vehicles was made up and fitted throughout with this system. It was hauled to the section running through the Allegheny Mountains, which had been the testing ground for the "straight-air" brake a few years before. Here every conceivable condition which was likely to be encountered in railway operation, including locomotive failure and breakaways, were carried out, but the brake proved equal to every emergency, and able to bring a train to, and to hold it at, a standstill even upon the steepest gradients.

But it was in 1887 that the Westinghouse system was subjected to its most critical test, and in competition with other systems. An elaborate series of trials was inaugurated by the association of the American firms specialising in the manufacture of railway vehicles to determine the suitability of the system for goods wagons, which in the United States are far larger and heavier than those used in these islands, and on which the urgency of brakes had become only too apparent owing to the frequency of accidents to goods trains.

The trains comprised fifty vehicles, and the tests were spread over a prolonged period, so as to secure every possible detail of information which was essential to the manufacturing firms. These tests were vital because the issue had reached the point as to whether goods wagons should or should not be fitted with brakes, and, if so, which system was the best adapted for all-round working.

The results were somewhat surprising, because they proved only too conclusively that none of the systems submitted to the ordeal, including the Westinghouse, was completely reliable or adequate. Certainly the results were not sufficiently satisfactory to warrant the immediate installation of the brake upon goods wagons. It was observed that a relatively long period elapsed between the exertion of the braking effect upon the first and the last vehicles, the result being extreme bumping and heavy shocks, recalling miniature collisions. This defect was fatal.

But Mr. Westinghouse proved equal to the emergency. He realised the weakness of the system, and instantly took steps to overcome it. The train with which the Westinghouse experiments had been conducted was left at Burlington, and Mr. Westinghouse returned home with his thoughts centred upon the subjugation of this latest and unexpected difficulty. During these experiments he suddenly recalled another feature concerning the quick-acting and sensitive valve of his train-signalling device, and thereupon decided to test it in connection with the triple valve upon his brake. It completely established its suitability for this purpose, and was accordingly incorporated.

Then the inventor effected another improvement. In the former instance the air in the train pipe was permitted to escape into the air at only one point. While the fall of pressure in the train pipe brought about the immediate application of the brake upon the vehicle near the point of escape, it was some time before the pressure within the train pipe at the rear of the train had fallen to an equal degree, thereby bringing a corresponding braking effect to bear upon the last vehicles.

The new improvement comprised a means of permitting the escape of air to the requisite degree from the train pipe beneath each vehicle almost at one and the same time, and this is where the sensitive valve plays its vital part. When the pressure is released in the train pipe beneath the car immediately following the locomotive, the quick-acting valve instantly transmits the fall in pressure to the succeeding car, causing a certain volume of air to escape from the train pipe beneath that vehicle. The effect is then handed on to the third car, when a similar result takes place, and so on until the train pipe beneath the last vehicle ejects its proportion of air. This serial transmission takes place so quickly that it was found possible, when another trial was made with the fifty-wagon goods train at Burlington, to bring about the full application of the brakes throughout the length of the train in one-sixth of the time previously required; while not only was the train brought to a stop within a shorter distance, but even under emergency or sudden braking conditions, bumping and shocks were reduced to an almost insignificant degree.

These later trials with what was *now* described as the "quick-acting automatic brake" made the strongest appeal to railway officials. At last they had been brought within reach of a device for which

Photo by courtesy of the Westinghouse Brake Co., Ltd.

THE TRIUMPH OF THE WESTINGHOUSE BRAKE

A striking test. The train, comprising the locomotive and seventy-five goods wagons, is being held stationary on a gradient of 1 in 40 by the Westinghouse atmospheric brake. The rear van is sixty-six feet above the top of the engine's funnel.

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they had long been searching, inasmuch as it complied with all the varied requirements of railway operation. The fifty-car goods train was dispatched upon a circuitous route through the eastern States to demonstrate the advantage of the new brake at various railway centres. It was a triumphant journey of several thousand miles, because, even at fifty miles an hour, this long train was proved to be under perfect control and capable of being pulled up within a short distance, smoothly and quietly. Each demonstration brought its immediate order for brakes for goods trains, the result being that by the time the train reached home the works were overwhelmed with contracts. It was the success of these tests which shortly afterwards led the American Government to pass a law compelling the fitting of such a brake to all goods wagons, and that within a specified time. Ultimately this limit had to be extended because it was found to be physically impossible to equip all the vehicles in the country within the time set down by legislation.

The triple valve constitutes the secret of the success of the quick-action automatic brake, and it is a significant fact, despite the vast improvements which have been effected in the Westinghouse system, that this device, introduced into the invention for the first time about 1870, has ever since been retained: it still constitutes the brain of the brake. True it has been improved, its functions have been extended, and many new duties have been assigned to it; but fundamentally it remains the same to-day as it was forty-five years ago.

Yet the quick-action automatic brake did not represent finality. Scarcely had it been adopted upon all the American railways as by law ordained, when new conditions arose and had to be met. Train speeds were increasing, the length and weight of trains were growing, while more frequent services were being brought into operation. These factors demanded that the brake should have still greater stopping power, especially in cases of emergency; and the fulfilment of these requirements brought about what is known as the "high-speed" brake, in which the features of the former brake are preserved, together with the capacity to act equally reliably and satisfactorily under the highest speed conditions. The feature which brought about this success was the embodiment of another valve, known as the high-speed reducing valve, the characteristic of which is the limitation of the braking effort to the necessities of safe and necessary operation under service conditions, coupled with the ability to increase this pressure considerably to make sudden emergency stops.

But even this improvement did not offer full provision for all phases and developments in railway operation. The next step was the evolution of what is described as the "ET locomotive" brake, which indicates an automatic air-brake for the engine and tender of the locomotive respectively, in addition to the train brake, of which it is independent. Up to this time the application of the brake to the locomotive had been designedly ignored, for the reason that it was really considered unnecessary and might contribute to greater wear and tear, and consequently maintenance expenses. But the "ET locomotive" brake fulfils its peculiar function in the safe and economical working of trains. Thus, if desired, the locomotive brake can be released while the train brake is still applied, or the train brake may be released without the locomotive brake. The train brake can be applied independently of the locomotive brake, or the latter can be brought into action without the train brake. The advantages of such a system are manifold. Thus, in descending long inclines, such as the flanks of mountain ranges, the driver gently applies the train brake to keep it under control. After a while he removes the braking effect from the train to the engine, thereby permitting the reservoirs under the carriages to be recharged. When this is accomplished, braking is transferred again from the locomotive to the train. This alternate action may be continued as long and as frequently as the driver may desire, and when the occasion arises the full braking effect may be instantly applied both on locomotive and throughout the train.

The majority of people look upon the automatic brake merely as a protective device. When a train, travelling perhaps at sixty or more miles an hour, pulls up suddenly, but without the slightest jolt or jar, one does not marvel. The result is put down merely to the brakes. Never a thought is given to the ingenious, simple, and effective mechanism placed beneath the carriages, and upon which the safety of the train depends. Probably not one in a thousand ever gives a thought to the enormous work which has to be performed by the brakes in making a sudden stop. But it may be brought home very easily. A heavily laden express train, scaling say 500 tons, sets out from the terminus upon its hundred or more miles non-stop run. A clear road, and the driver commences to work his engine up to sixty miles an hour. If the conditions are favourable he may have brought the train into its swing in about six minutes, during which time he has covered some three and a half miles. Presuming the track is perfectly straight and level, we will suppose that he shuts off steam at this point, and allows the train to run on until she stops of her own accord—that is, from friction and the resistance of the air. Under normal conditions the train will run on for approximately another 24,000 feet—about four and a half miles. But if the Westinghouse brake is applied when the train has attained sixty miles an hour it can be brought to a dead stop within 1,000 feet and in about twenty seconds. In other words, the brake is capable of overcoming the energy possessed by a train travelling at sixty miles an hour, and which it has taken some six minutes to attain, within a thirtieth of that time and one-eighteenth of the distance.

The brake fails to arouse attention among the travelling public because it is scarcely ever seen. It is stowed beneath the carriage out of sight and virtually out of mind. The only visible feature of its existence may possibly be the air-pump upon the locomotive. If the brake were within the field of visibility it would command more attention, provoke thoughts of wonder, and be considered a marvel of human ingenuity. Consequently, very few people appreciate the fact that the relatively small contrivance mounted beneath the coach whereby the retarding of the train is brought about, is much more powerful than the huge, gaunt locomotive which hauls the train and which is ever an object of admiration. Moreover, speeds rise, the trains grow longer, more powerful locomotives are employed, and the carriages increase in dimensions and weight, with the result that the minds responsible for the designing of the brakes are ever keyed up to concert pitch. If the brake which was adequate for the train of twenty years ago, and which was capable of pulling up a mile-a-minute express of that time within 1,000 feet, were mounted upon a flier of to-day, it would be virtually useless. It would not pull up the modern train within less than 1,760 feet in an emergency. When passing the 1,000-foot mark, where the train of twenty years ago came to a dead stop under brake application, the modern express would still be moving at forty-three miles an hour.

But the railway man differs in his attitude from the travelling public towards the air-brake. To him safety, while vital, is in reality a secondary consideration. He considers the device rather from the financial aspect, and the automatic air-brake has proved to be one of the greatest money-makers of the day in the railway world. It has facilitated the higher speeds, which in turn affect the number of trains that can be run over a length of line during the twenty-four hours. It has enabled larger carriages to be employed, which means that so many more passengers can be carried per train and for every mile run by the train. The carrying capacity of a train to-day is about three times what was possible twenty years ago. In other words, one train is run now to handle the traffic for which three trains were necessary two decades since. This means economy, which in turn spells greater revenue with less expense. And the trains may be stopped and restarted as often as desired during the run, and that without the locomotive and carriages suffering the least damage. These are the reasons which cause the railway world to regard the air-brake as a money-making invention.

Although the air-brake has been brought to a high standard of perfection, finality has not been reached by any means. New issues and factors are arising every day which have to be met. The electric train, upon its appearance, precipitated many problems which had not arisen before. It was not merely an application of the steam train brake to its electric rival. The conditions were so vastly different. All that could be done was to take the fundamental principles which had established their value in steam train operation, and to evolve a new brake equally efficient for the new system of locomotion. For forty-five years, from the day when he first embraced the idea until his death, Mr. George Westinghouse never left the child which brought him fame and fortune, and this despite his activity in other fields. It was his first care throughout the twenty-four hours, and he found the struggle to keep pace with railway progress exciting and energetic—one which appealed to his temperament and genius in attacking intricate and perplexing problems as they arose.

CHAPTER VII

The Telephone

THE steam packet, which had been tumbling for days among the waves of the Atlantic, was safely berthed at last. The engines were rung off and the gangways were thrown out. Down one of these links between ship and shore hurried a healthy young Scotsman, who had decided to try his luck in Canada ; not that the Homeland had been unkind to him, but because the call of a new country refused to be stilled.

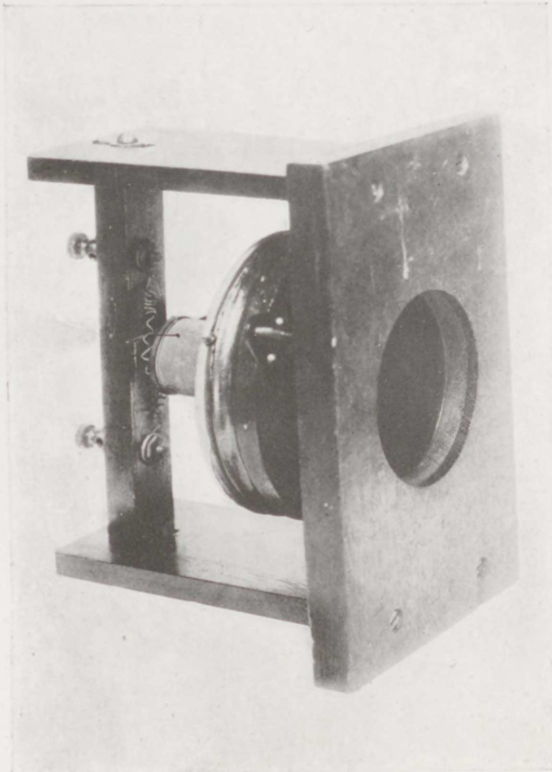
Although only twenty-three years of age, Alexander Graham Bell had become pretty well known in British scientific circles. His father, Alexander Melville Bell, had achieved world-wide fame as the inventor of " visible speech," while he was the dean of British elocutionists. Young Alexander first went to school in his native city, Edinburgh, completing his education in London. He speedily revealed the fact that he inherited his father's abilities, because at sixteen he was teaching elocution in our schools.

But while elocution was his profession there were three hobbies which appealed irresistibly to him. These were music, electricity, and telegraphy respectively. Every available minute was turned to one or other of these studies, and his enthusiastic interest therein was sustained by the scientists with whom he became acquainted, while his achievements in connection with acoustics were considered to be of such pronounced significance that he was strongly urged to continue his researches and experiments in this field.

Twelve months after landing in Canada, young Bell's work had commanded such attention that he was offered, and accepted, the appointment of Professor of Vocal Physiology to the University, Boston, in the United States. Here his system of teaching deaf mutes, which he had evolved and perfected, aroused intense interest. In fact, young Bell was so impressed with the success he achieved that he relinquished his Professorship to open a school of his own to continue his work upon a more comprehensive and individual scale. To this end he went to reside with one of his deaf-mute pupils, Georgie Sanders, at Salem, the famous port and city sixteen miles out of Boston.

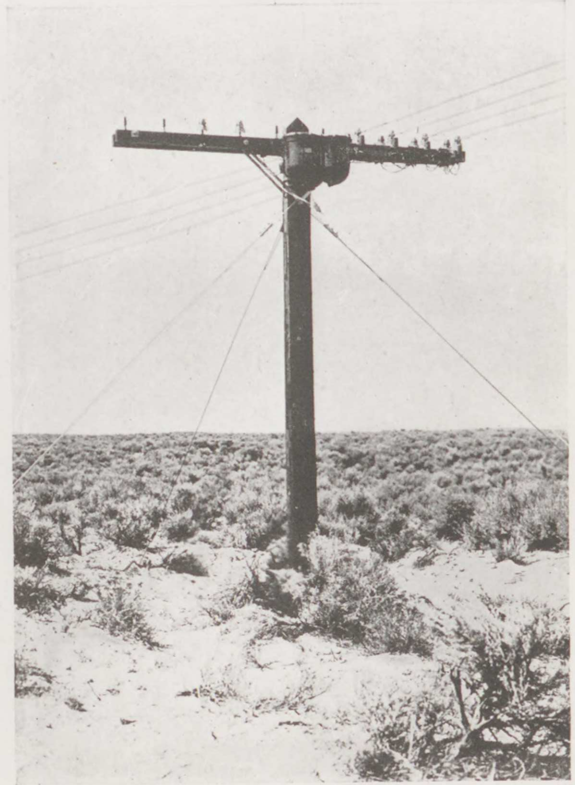
Although deeply immersed in his professional occupation, Bell did not by any means neglect his hobbies. Owing to the absence of better facilities he rigged up a small laboratory in the cellars of the Sanders' home, and to this underground study he repaired upon the conclusion of his school duties. By this time his hobbies had secured such a firm grip of him that he invariably laboured alone until the early hours of the morning.

Working among his hobbies brought to him an idea which he could not shake off. If it were possible to send signals and even to converse over a wire in the language of the Morse code, why should not one be able to send vocal speech directly over a wire? The more he dwelt upon the problem the more convinced he became as to its feasibility. But



THE FIRST TELEPHONE

Professor Bell's Original Telephone, exhibited in 1876 at Philadelphia. It was known as the "Gallows Frame," and through it the first words ever spoken over a wire were heard by the inventor's associate, Thomas A. Watson.



THE SECRET OF LONG-DISTANCE TELEPHONY

By means of the Pupin loading coil (shown at the top of the pole in the photograph) it is possible to telephone between New York and San Francisco, 3,390 miles. The coil is placed at every eighth mile. 13,600 miles of wire $\frac{4}{1000}$ inch in diameter were used in these coils.

after a little reflection he forced the thought into the background, partly because his experiments to this end proved such disconcerting failures. It was ultimately submerged by another idea—the transmission of a number of messages at the same time in the Morse telegraphic code over a single wire. He called it the "Harmonic Telegraph," and he depended for his success upon the law of sympathetic vibrations. An intermittent current of a given musical pitch was produced by each transmitter, to which the receiver responded when its spring was tuned to that particular note. But the crux of this problem was that the sympathetic springs—that of the transmitter and the receiver respectively—had to be dead in tune to prevent any conflict in the telegraphic signals.

In the quest of this issue the cellar laboratory in the Sanders' home became a maze of tuning-forks, electro-magnets, and electric batteries. But although the harmonic telegraph claimed the first and foremost attention of the young investigator, the idea of talking over the telegraph wire still lingered at the back of his brain. He kept it under restraint, thinking that perhaps, while working out the harmonic telegraph, some phenomena might be revealed which would lead to the realisation of the talking-wire problem.

But the harmonic telegraph proved an exasperating field for experiment. The greatest difficulty was to keep the springs in tune. He would sit in a room with a receiver pressed to his ear so as to be able to compare the note or pitch of its spring with that of the transmitter which was vibrating in the cellar laboratory. True, his springs were not ideal for the purpose, seeing that they were only flattened pieces of the springs which are used to actuate the mechanism of a clock, but they sufficed for his purpose.

By the winter of 1874 Bell had reached a point beyond which he could not advance with the limited resources of his own laboratory. Accordingly, one day he set out to the workshop of Charles Williams, 109 Court Street, Boston, his idea being to have superior instruments built by expert hands to his designs. Williams's workshop was the Mecca of all young inventors for miles around, because the owner was sympathetic and encouraging. He employed from forty to fifty hands, and possessed that rare attribute of being an excellent judge of men. If any of his employees manifested any desires to improve their mechanical knowledge he allowed them to do so, and, moreover, was able to determine from close observation the particular channel of mechanics in which a workman excelled and betrayed the greatest enthusiasm. He encouraged his men to embrace the field which made the greatest appeal to their individual tastes, and at the same time placed a premium upon initiative among them.

Among his employees was a young man who entered his service because he had grown dissatisfied with writing letters, book-keeping, and carpentering, at which he had earned his living since he was thirteen. This young man's name was Thomas Augustus Watson, whose education had been only that offered by the Salem public schools, supplemented by individual study at night. He had an intense love for science, especially mechanics and electrical engineering, which in those days was in its extreme infancy. His employer, Williams, detected this fancy and gave it every possible inducement, with the result that Watson soon found himself in an ideal world among galvanometers, telegraph keys, electro-magnets, relays, and other similar paraphernalia pertaining to the comparatively young art of telegraphy. When work was slack in this branch he willingly embraced any other duty, his greatest achievement being the construction of a steam engine, which he built to an order, when business in the electrical branch was exceedingly dull.

Under these circumstances Watson was entrusted with a considerable amount of the most delicate and difficult work which entered the shop, more particularly the evolution of ideas for inventors, which tasks, it may be mentioned, held an indescribable attraction for him. On the day when young Alexander Bell called at Williams's workshops young Watson, then only twenty years old, was busily engaged in working out an experimental torpedo-exploding apparatus.

When Williams had learned the object of Bell's visit he suggested that Watson should fulfil Bell's ideas, but would the inventor wait until the torpedo-exploding apparatus had been completed? Bell and Watson had been introduced to each other, and a mutual interest had sprung up between them instantly, Bell feeling convinced in his own mind that Watson was the very man to build his instruments, while Watson himself was fascinated by the harmonic telegraph idea. Bell accordingly accepted the services of Watson, who would be available directly the task upon which he was then engaged was finished.

Watson afterwards built two sets of the harmonic telegraph for Bell, comprising three transmitters of different pitches, three receivers with springs tuned to the same pitches, three signalling keys, and a galvanic battery. One installation was placed in one room and the other set in another room at Williams's workshops. While these preparations were under way the two men came closer and closer together. At night time, when his daily task was ended, Watson would spend his evenings with Bell in the cellar at the Sanders' home, and in this manner there began that close association which has never been completely broken, and which for many years was extremely intimate.

It was the afternoon of June 2, 1875. Bell was sitting in one of the rooms in the Williams establishment in which his transmitting apparatus had been set up, while Watson was in the other room. Experiments were in active progress over the single wire which connected the two rooms. The day was hot and the weather sultry, and even the springs of Watson's instruments apparently had become infected with climatic lethargy. The spring would persist in sticking to the pole of its magnet through magnetisation. Watson repeatedly knocked the spring free, but the persistence in sticking became exasperating. At last, in sheer disgust and when the spring had adhered with unusual tightness, he gave it some particularly vicious snaps to induce it to vibrate freely, accompanying the action with some decidedly uncomplimentary remarks.

IN A LARGE TELEPHONE EXCHANGE (Avenue, London)

Showing the operators at their switches

In the other room Bell was sitting patiently making some slight adjustments. Presently, to his astonishment, he saw one of the receiver springs commence to vibrate violently for a second or so. Then it would stop, only to resume the vibration a little later. Bell sat bolt upright, unable to divine the reason for the uncanny action, because no keys were being depressed to set up such movements. After observing the strange, and to him inexplicable, action for a few seconds, he grabbed the receiver and placed it against his ear in the effort to discover what kind of current was at work. To his intense surprise he heard a faint twang, and he recognised the twang as belonging to one of the transmitter springs. The twang was heard distinctly several times, so that his ears did not deceive him. Highly excited, Bell rushed into Watson's room to see what he was doing.

He found his colleague banging away viciously at the spring which had stuck to the pole of its magnet. Bell watched the snapping repeated at irregular intervals for a brief period. Then he startled Watson, who was preoccupied in his task, by announcing that he had heard the twanging of the rebellious spring in the other room.

The two men looked at one another with astonishment. And no wonder. Never before that moment had a real sound been transmitted and heard electrically over a wire. The sticking of the receiver spring which had provoked Watson had solved the problem which lay at the back of Bell's brain, and with which he had been wrestling for so many years. The thin strip of magnetised steel set into vibration over the pole of its electro-magnet by Watson's snapping had generated an electric current which fulfilled fully Bell's dream of being able to talk by telegraph if once a means could be discovered of causing a current of electricity to vary in its intensity in precisely the same way as the air waves vary in density during the production of a sound. As Bell explained his theory, Watson listened in amazement, which became accentuated when Bell advanced the opinion that if an instrument could transmit one sound so perfectly it should be possible, by introducing modifications, to transmit any sound, and even the human voice!

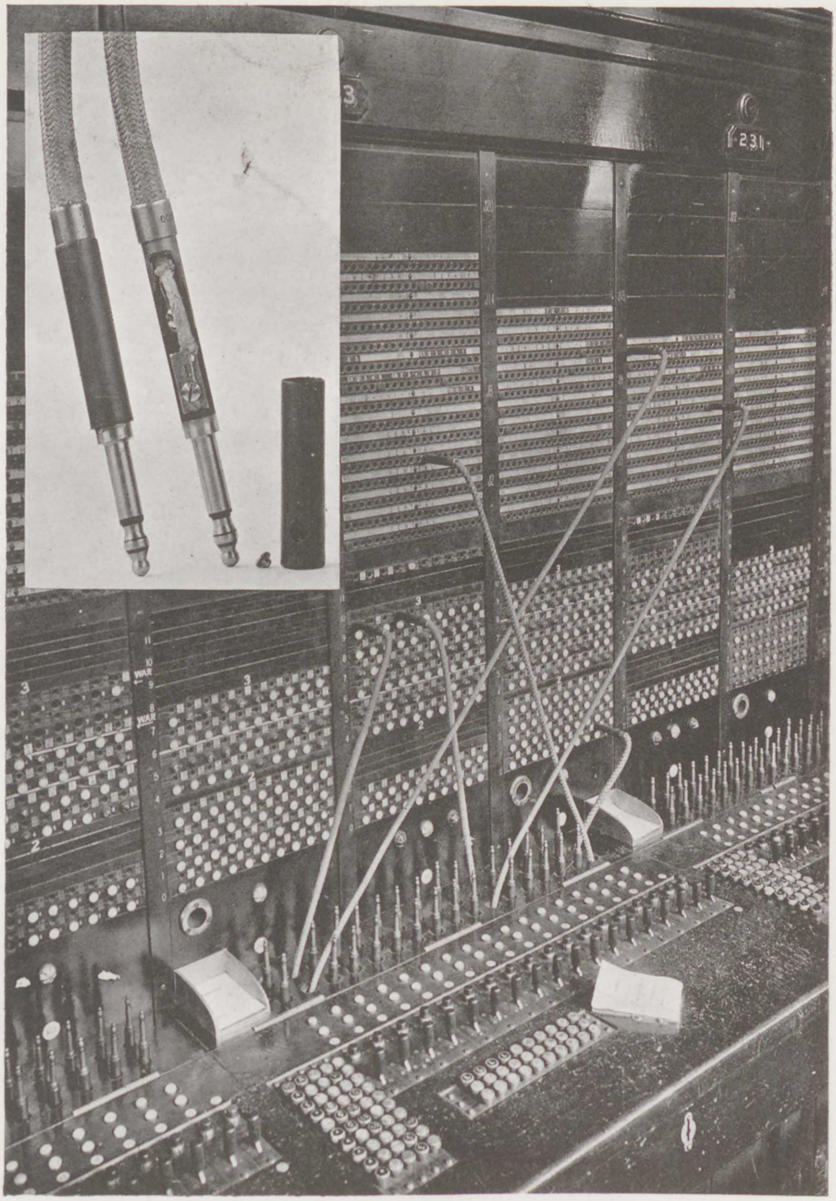
The excitement of Bell and the sensation of being upon the verge of a great discovery drove all the tired feeling out of Watson. The two men spent the whole afternoon twanging springs and trying various combinations as they occurred to them. While Bell was experimenting he was thinking hard. Before they finished work, long after the sun had set, Bell had prepared a rough idea of his conception for a talking-wire or telephone, which he urged Watson to make as soon as he could. He directed Watson to take one of the harmonic receivers and to attach it to a drumhead, expressing the firm conviction that when he talked against the drumhead, the spring attached to it would be compelled to follow the vocal vibration and transmit articulate speech instead of merely its own monotone twang.

Watson by now had become so infected with Bell's excited enthusiasm that he commenced the construction of the instrument roughly outlined by Bell directly the twain parted that afternoon. By toiling diligently far into the night Watson had the instrument ready for trial the next day. The test to which it was submitted substantiated Bell's theories right up to the hilt—the drumhead transmitted the tones of the human voice—and thus the telephone was born on June 2, 1875.

Flushed with this success, Bell devoted his energies to the improvement of the apparatus, a task which occupied considerable time. Meanwhile, realising the far-reaching possibilities of conversing over a wire, Bell prepared his patent claims to ensure that he should receive the due reward for his industry, ingenuity, and knowledge; and on February 15, 1876, he filed his application in the Patent Office of the United States. This patent claim subsequently aroused considerable attention, inasmuch as it is acknowledged to be one of the most perfect and comprehensive specifications which has ever been drawn up, claiming, as it did, every feature pertaining to the ability to talk by electrical agency over a wire.

But Bell had not been alone in his efforts to achieve the apparently impossible. Unknown to him, two other investigators had been attacking the selfsame problem. They, on their part, were quite ignorant of the Scottish worker's researches and experiments. One of these had completed what was in reality a telephone, but with which he made no attempts to discover whether it would or would not transmit articulate speech until Bell's patent had been filed. This was Mr. Thomas Alva Edison, and he similarly had evolved his instrument while pursuing the quest upon which Bell had been engaged for so many years—the harmonic telegraph. When news of Bell's patent reached him, Edison at once subjected the instrument, which he had contrived some time before, to the telephone test, and to his surprise he discovered that he could also transmit the human voice by electrical means over the wire. The surprise is that Edison had never made such an experiment earlier, because if he had done so he certainly would have anticipated the Scottish experimenter's achievement. Nevertheless, Edison has always ungrudgingly extended the merit of inventing the telephone to Bell, because the latter definitely established the ability to talk by wire.

The other inventor in the field was Elisha Gray, of Chicago, who was also a great authority upon sound. He devised an instrument which was capable of transmitting the human voice over the wire, and, strange to say, he lodged his patent with the United States Government on the same day as Bell. In this manner a situation, which it is difficult to parallel in the realm of invention, was precipitated. Examination of the two applications revealed the astonishing circumstance of two men advancing the selfsame claims and covering virtually the selfsame ground, although they had been working independently and unknown to each other a round thousand miles apart. Now, since it was absolutely impossible to grant two patents to two inventors for the selfsame discovery, one of the two had to be given priority and extended the patent protection of the Government. This issue could only be determined by ascertaining the precise time at which each had deposited his application. The inquiry in this direc-



FRONT OF POSITION WHERE CALLS ARE ORIGINATED

The inset picture shows the plug by which connections are made

tion proved that Bell's application had been the first to be received, and accordingly his application was accepted and the patent ultimately awarded to him. It was a fortunate circumstance for Bell, because he only reaped the fruits of his labours by a matter of minutes.

Bell realised that his instrument was primitive, and that many improvements would be necessary before the invention could be described as being commercial. But stories of what he was doing in the way of talking over the telegraph began to be circulated and magnified, and inquisitive visitors to Williams's workshop became too numerous. Bell grew apprehensive of this publicity, so he removed his instruments from those workshops to the security and obscurity of two rooms on the top floor of a cheap boarding-house, No. 5 Exeter Place, Boston. The upper room he equipped as a laboratory, while the other room, beneath the former, was his living- and bedroom. At his suggestion, Watson rigged up two copper wires between the two rooms, and in this seclusion the commercial telephone was worked out, Watson, who had severed his connection with Williams, assisting in the enterprise. These arrangements were quickly completed. Then Bell in one, and Watson in the other, room sat at the instruments patiently for hours on end striving to transmit and to receive sentences spoken by the human voice over the telegraph wire. Progress was slow because innumerable modifications and adjustments had to be carried out. Some human tones would be heard distinctly, but others could not be heard at all.

But the afternoon of March 10, 1876, brought the due reward of perseverance and patience. Watson receiver glued to ear, suddenly started. Sharply and clearly rang out the words spoken from the upper room:

"Mr. Watson, come here, please; I want you."

The listener dropped the receiver, paused for a second, and then, rushing from the room, darted up the stairs, two at a time, to burst into Mr. Bell's room, shouting, "I heard you: I could hear what you said!"

The words Watson had heard comprised the first sentence that had ever been transmitted over a telephone wire by the human voice. Two years later the laboratory in the attic was broken up and dismantled. Watson took down the historic short length of wire over which conversation by articulate speech had first been maintained, coiled it up, and wrapping it carefully in a protective covering, inscribed upon it what it was. For thirty years it remained in his safe, but in 1913 he handed it over to the chief engineer of the American Telegraph and Telephone Company for preservation in its museum. Subsequently the wire was brought into use upon another historic occasion, which is described later.

But up to this point Bell had never tested his instrument outside his laboratory. On October 9, 1876, the inventor felt that he had advanced it to a sufficiently perfect stage to warrant a test on a real live wire. Accordingly, he and Watson sallied out, and the instruments were connected up to a telegraph line two miles in length extending from Boston to Cambridge. Talking was attempted in one direction only, and Watson cherishes vivid memories of that day, and his fear that the instrument would fail to work after all. He held on to the receiver, but his heart sank as he failed to catch the slightest sound from Bell, who was posted at the transmitter. Presently he caught the faintest sign of his comrade's voice. It increased in loudness and clearness as Bell made one or two adjustments, and at last the human tones became more distinct than they had ever been in the laboratory.

Bell, in common with every other pioneer, considered that he had perfected an invention which was destined to influence the whole trend of civilisation. It was such a remarkable achievement that he concluded the public would jump at it. But he was destined to speedy disillusionment. The public would have nothing to do with it. The company which was founded to exploit his discovery, and which was created with little capital, comprised four men: Alexander Graham Bell, Thomas A. Watson, Gardiner G. Hubbard (the inventor's father-in-law), and Thomas Sanders, the father of the deaf-mute pupil, in whose home Bell had set up his cellar laboratory, and who constituted the sole financial support to the scheme.

Bell and Watson strove hard to induce the public to appreciate the invention. The two stumped the eastern States, giving demonstrations. Bell would set up his receiver in the room in which he delivered his lecture of education, while Watson sat in another room, speaking sentences into the instrument and which at the receiver were reiterated with sufficient volume to be heard by one and all there assembled. But the public laughed. They described Bell as an impostor, and that there was no wire talking at all, but that the so-called inventor was really a clever ventriloquist. The least sceptical described the invention as a wonderful scientific toy, but that it never could be adapted to enable conversation to be maintained easily over hundreds of miles. Such a suggestion was absurd! When it came to Great Britain it was described as "the latest American humbug," while the inventor was roughly handled as a "crank," a "charlatan," and other similar and more or less uncomplimentary terms.

The hostility to the new invention was accentuated by the machinations of a powerful rival—the Western Union—which held the telegraph monopoly in the United States. In the telephone it saw a menace to its interests. At first it strove to ridicule the new idea, and then to defeat it, sparing no agency to this end. Then subsequently realising that the telephone had come to stay as a result of the development in the city of Boston, it also decided to exploit the invention. To this end it enlisted the services of all the most clever scientists in the country—men such as Elisha Gray (who had failed to secure his patent owing to being forestalled by Bell), Edison, Emile Berliner, and other equally brilliant minds. They attacked the problem, and with their extensive and combined knowledge they succeeded in evolving many important and decided improvements in details.

In 1877, Alexander Bell, who acknowledged his deficiency in commercial transactions, virtually withdrew from active participation in the exploitation of the telephone. He had provided the foundation for a far-reaching and elaborate structure, and he left the building of the fabric to other more competent men. But the early days of the pioneer company were dark indeed. Lack of funds was sorely felt, while the rival was applying the pressure of competition very tightly. Matters rapidly approached a crisis. Sanders, who had supported the idea with the whole of his fortune, saw himself confronted with bankruptcy. It was only the optimism and doggedness of Hubbard which kept things going. Then came the turning point in the fortunes of the telephone. Hubbard realised that a man of tremendous energy, imagination, determination, and commercial ability was requisite to handle the reins. He made up his mind to secure such a controlling force.

At that time a young man who had organised the mail service of the United States was quarrelling with an unsympathetic Government. His work was appreciated, but the powers that be did not think he was worth his salary of £700 per annum, and they forthwith reduced it. The young man, Theodore Newton Vail, who had started life as a telegraph operator and who had risen rapidly to his responsible position, entertained quite a different opinion, with the result that he bade farewell to the mail service. Hubbard got into touch with Vail, offered him the supreme position in the telephone company, promised him the salary which the Government had refused to pay, and gave him a free hand. Young Vail had heard of the telephone and was keenly interested in it. He saw that if properly handled it would become one of the greatest commercial assets of the day and become indispensable to everyone.

Vail accepted the post with enthusiasm, and although money was so scarce that he often had to rest content with but a fraction of his salary, he buckled into his new and difficult task with unbounded zeal. He gathered together the tangled skeins of the idea and set about organisation upon an extensive scale. At the time he came upon the scene there were not more than a thousand telephones in use in Boston, and he speedily observed that the young invention was suffering from strangulation. It was healthy, and wanted to stretch out in all directions. Forthwith he decided to give it all the elbow-room it required. Numerous other companies had commenced operations, and their competition was hitting the pioneer company extremely hard.

In 1881 Alexander Bell came to England with the idea of persuading its introduction here. But it was a terribly hard uphill task, accentuated by the fact that rival interests were pushing the Edison telephone with all the zest they could command. The latter established an exchange, which was the suggestion of a Hungarian, in Queen Victoria Street, in which Mr. George Bernard Shaw served as a switchboard operator. Finally, as is well known, an organisation, the National Telephone Company, received a franchise from the British Government to embark upon the commercial exploitation of the idea. Subsequently, Bell returned to the United States and abandoned telephone inventions completely, concentrating his energies mainly upon the problem of dynamic flight, although he attacked such side issues as the talking machine, the scientific breeding of sheep, a new metric system, and food preservation. Watson stayed with the company until 1881, when he too terminated his connection with telephones, came to Europe for a rest, and two years later returned home to devote his attention to the building of battleships. In this work he founded what is to-day the largest shipbuilding concern in the United States, from active participation in which he retired in 1903 to enjoy well-merited rest in the country.

Meantime, Theodore Vail was commencing to exert his influence, and in no uncertain manner. He saw that the telephone, if confined to the limits of a town or city, could never become a pronounced success, either financially or otherwise. He urged that it was necessary to link up cities, towns, villages, hamlets, and even isolated homes, bringing one and all into a huge intercommunicating network. People laughed at the idea, which they described as a wild and impossible dream; but the man at the reins remained unmoved by gibe or ridicule. He had a commanding and persuasive manner with him which none could overcome. If he wanted any money to fulfil a dream he always succeeded in getting it. Financiers might raise objections, criticisms, and even demur, but eventually they came round to his views.

Vail's first proposal was startling, in very truth. He decided to link Boston with New York by telephone. A vigorous attempt was made to dissuade him, but he refused to be thwarted. His first connecting link of this character was sixteen miles in length, between Salem and Boston, the two towns which had played such a prominent part in the story of the invention of the telephone. It was a trunk line and the first of its type, so that Vail is deserving of full credit as the father of the trunk telephone line. As people in Salem were able to talk to folks in Boston as easily as if they were standing side by side, Vail decided to bring Boston and New York into conversational touch. It was a big job for that time, as 243 miles separated the two cities. But it was done.

This success prompted Vail to embark upon a dream which he had long been nursing—talking across the breadth of the North American continent, thereby linking San Francisco with New York. The enterprise was staggering for those days, and could not be carried out in a single step. So he decided to move across the continent by instalments. Chicago, 900 miles distant, was his first objective, and on October 18th, 1892, Mr., now Dr., Alexander Graham Bell inaugurated this section by carrying out the first conversation by telephone between New York and Chicago.

But the initial move across the continent at first proved a dismal failure. Neither New York nor Chicago regarded the innovation with enthusiasm. Commercial men in the two cities preferred the mail or the telegraph, although both were hours slower. Vail strove might and main to educate the public to the advantage of talking over the wire between the two points, but without success. The line was a failure; so much so in fact that it became nicknamed "Vail's Folly." But suddenly it woke up. Commercial men and private residents realised that they were by no means such hustlers as they professed to be. Forthwith there ensued a rush for talking between the two cities, and the popularity of the line grew so rapidly that it was not long before it became a complete financial success, and to-day ranks as the hardest worked 900 miles length of telephone trunk road in the world.

Now the movement across the continent was revived and accelerated, Omaha, 300 miles beyond, was the next objective. Then without pausing, the linemen continued on to Denver, which city was switched into New York, 2,100 miles, in 1911. By 1913 the length of the transcontinental was increased to 2,600 miles by tacking on the 500 miles section from Denver to Salt Lake City. While this latter section was in progress arrangements for completing the last span to the Pacific coast were hurried forward, and this final span of 800 miles was completed with such celerity, despite the fact that broad expanses of desert, salt sinks, and the towering Sierra Range had to be overcome, that San Francisco was brought into conversation with New York on January 25th, 1915.

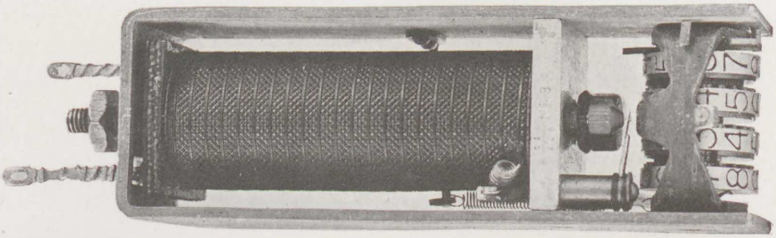
The transcontinental line ranks as one of the two longest stretches of trunk telephone road in the world. It is 3,400 miles in length, and in the provision of the two circuits 6,780 miles of copper wire, about one-sixth of an inch in thickness, have been used, strung upon 130,000 poles, and having an aggregate weight of 5,920,000 lb. A few months after the completion of the American transcontinental telephone line the Dominion of Canada was spanned in a similar manner by the selfsame company, the length of the line being 4,200 miles.

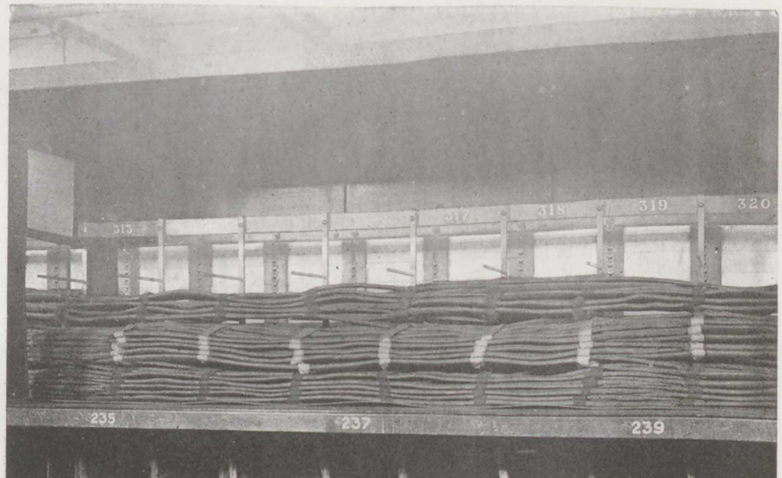
The realisation of such long-distance telephony was brought about by the wonderful invention of a

Serbian engineer residing in the United States—Dr. Michael Idvorsky Pupin. Some years ago this scientist discovered a means of increasing the self-induction of the circuit, thereby maintaining the strength of the currents or waves sent over the wire. His device was a coil, described as a "loading coil," which was introduced into the circuit. But the coil, as then devised, was cumbersome and expensive, since thick copper wire was used. Yet the coil was adequate to demonstrate the value of the invention, and forthwith it was purchased by Mr. Vail, who handed it over to his own engineers for improvement. As a result of the combined efforts it was found possible to reduce the size of the coil and to use wire of hair-like thinness. These coils are introduced at intervals of eight miles along the 3,400 miles of the transcontinental wire. In their construction 27,300 miles of fine wire, four-thousandths of an inch in diameter, were used.

The opening of the transcontinental system was historic in more senses than one. It was inaugurated by Dr. Graham Bell, who was seated at the New York end, while Mr. Watson was at the San Francisco terminus. During the opening ceremony the original transmitter which Dr. Bell had used on that historic afternoon of March 10th, 1876, was coupled up, and the first sentence sent over a telephone wire: "Mr. Watson, come here, please; I want you," was repeated.

Although the transmitter had been improved out of recognition during the passage of forty years, the words were reheard with perfect distinctness, though not quite so loudly, by the inventor's old colla-





BACK OF OPERATOR'S POSITION, AND REGISTER

The larger picture shows the cabling and the relay racks, the section where the little boxes are seen. The top picture is that of the register, which, operated by the telephone girl as she sits at her switch, records the number of calls a customer has.

borator. Moreover, a section of the wire used in the Boston workshop, which Mr. Watson tore down for preservation as an historic memento, was also introduced into the transcontinental line.

At the opening of this long-distance wire all records in trunk road conversation were smashed. In addition to talking between New York and San Francisco, Mr. Vail, who was spending a vacation in Florida for the benefit of his health, was switched-in, thus adding a further 1,000 miles to the circuit. President Wilson, seated at his desk in the White House, Washington, also carried on a triangular conversation with San Francisco, New York, and Florida, while Boston was afterwards linked up. When one recalls that it was only with extreme difficulty that Bell could talk over a wire merely a few feet in length in 1876, the ability to converse over 4,400 miles of wire forty years later offers a striking testimony to the development of the invention and the brilliancy of the brains concentrated upon its improvement.

Some idea of what such a telephone line as this represents may be gathered from the fact that when two persons are talking between New York and San Francisco they have the exclusive use of an installation which has cost a round £400,000. A telephone differs from a railway line because only two people may use it at one time, whereas several trains, heavily laden with passengers and freight, may use a length of railway simultaneously. Under these circumstances the cost of telephoning across the continent, which is 27s. per minute with a three-minute minimum, cannot be described as excessive.

In Great Britain such lengthy trunk roads are impossible, owing to lack of opportunity. But there is telephonic conversation between various parts of the country and Paris, while previous to the outbreak of war Brussels was linked up with England. So far as distance is concerned, this may not compare with the overland of the United States, but at the same time it is decidedly noteworthy, because it introduces a length of sea-cable forming the middle section between the respective land spans.

Perhaps the most outstanding telephone achievement in England is the underground circuit which is being provided between London, Birmingham, and Liverpool. This undertaking was rendered necessary owing to the growth of the traffic between the three points. Fifty-two circuits are provided from the fifty-two pairs of wires forming the cable, plus a further twenty-six circuits, representing one circuit per two pairs of wire, formed by what is known as " phantom " circuit working. The total length of this underground cable is 202½ miles, comprising the first section to Birmingham, 110½ miles, and thence to Liverpool, 90 miles. At intervals of two and a half miles Pupin loading coils, similar to those used upon the United States transcontinental line and, in fact, built by the manufacturing branch of that organisation, are inserted. The weight of the wire used in this underground cable varies from 300 lb. per mile of wire for the two pairs forming the central core, 200 lb. per mile for each wire of the first layer of fourteen pairs of wires, and 150 and 100 lb. per mile for the thirty-six outer circuits, the whole being enclosed in a sheath of lead. The average diameter of the cable is a little less than 3 inches. In this underground trunk road approximately 1,375 tons of copper wire have been used.

During the trials with this underground cable some interesting achievements were recorded. At the transmitter in the General Post Office in London a person spoke and his words travelled to Birmingham and back, being received in another room in the General Post Office. Thus the voice travelled a distance representing a continuous line of 221 miles. Then four of the first layer circuits were coupled up and spoken through, the words travelling from London to Birmingham, back again to London, thence a second time to Birmingham and once more back to London, representing 542 route miles. Two additional loops, representing the central core, were now coupled in so that the voice had to travel three times to Birmingham and back, representing 663 miles. This distance coincided practically with a length of underground cable reaching from London to Aberdeen, and the results were considered to be completely satisfactory. As a final test two more loops of the first layer were brought in, causing the voice to make four round trips between the transmitter and receiver, the distance this time being equal to 884 miles of continuous cable, or approximately the distance between New York and Chicago. While speech over this reach was possible it was not considered commercially satisfactory. At the time this test was carried out it represented the longest distance over which conversation had been maintained with underground cables.

Although the telephone has made remarkable progress in Great Britain its growth is insignificant when compared with that in the United States. Naturally, this is only to be expected, bearing in mind the enormous size of that country. When Bell's telephone became recognised as an indispensable asset to commerce, companies sprang into existence all over the country. Each was alloted a distinct territory in which it was free to lay its wires and maintain intercommunication. But this arrangement had its disabilities, Some local districts were financially successful, others were failures. After having reorganised the Bell Telephone Company and having put it upon its feet, Mr. Vail retired from the scene of his labours and finally abandoned the telephone field altogether in 1890. He had set various schemes going, and they were meeting with success. It was merely a question of routine, which did not appeal to him; and he considered that he had done sufficient to merit a well-earned rest. The company with which he had been associated was recognised as the parent concern, and it drew heavy payments in licences from the numerous subsidiaries which were in operation throughout the United States. But it was realised that the subdivision into territories, each possessing its individual companies, possessed many drawbacks; it would be better, as Vail had prophesied years before, if they were all woven into a homogeneous whole.

Amalgamation was commenced, but it proved a costly process, and swallowed so much money with apparent little return that at last financiers point-blank refused to have anything more to do with the telephone. In 1907 the President of the Telephone

Company, which was capitalised at £60,000,000, resigned. In the search for a new president the directors turned to Theodore Vail, offering him a salary of £20,000 a year. He refused it, urging that at his age—sixty-two years—he had acquired all the money he would ever require. But the directors pointed out that as he had rescued the telephone when in its infancy he was needed once again to put the house in order. At last he was persuaded to re-enter the field of his former triumphs. Speedily gathering up the reins, he brought about the successful consolidation of the scattered companies and welded them into a harmonious whole. He not only revitalised the moribund concern, but he restored its former initiative.

That was in 1907, and to accomplish his ideals he spent money like water. The Panama Canal is generally regarded as the most costly single enterprise ever taken in hand, and in which the American people sank £62,000,000 in the course of nine years. But during the selfsame period the Bell Telephone Company, under Mr. Vail's direction, expended over £120,000,000 in engineering construction alone, and to-day it ranks as one of the biggest enterprises in the world, the whole system possessing 21,000,000 miles of wire, connecting 9,000,000 instruments.

In this work of consolidation Vail succeeded in wreaking a terrible revenge upon his old enemy, the Western Union, which had spared no effort in its attempt to stifle and kill the telephone when it was in its infancy. Vail re-entered the arena to find his whilom rival moribund and in danger of strangulation. He promptly acquired an interest in the competitor, and at last secured working control of it. Under his direction it was likewise rejuvenated, although this work was summarily interrupted by the Government declaring the combination illegal and compelling the Western Union to trade under its separate and distinct individuality as before.

Few people have any tangible conception of the principles governing the transmission of speech over a wire. We say that the voice is transmitted instantly, but, speaking from the strictly rigorous scientific point of view, a certain period of time is occupied in the transmission, although it is so minute as to be practically negligible. We all know that sound is caused by vibrating the air, and that by varying the tones the vibrations or waves are changed. When we speak into the transmitter of the telephone we set up a series of vibrations of the air. These air-waves have to be converted into electrical waves to flash along the wire. But the electical waves travel at a far higher speed than the sound waves. The latter are sluggish, moving only at 1,160 feet per second, whereas the electrical waves travel about 56,000 miles per second. Thus, if a person were to climb to the top of St. Paul's Cathedral and, turning towards Birmingham, were to hail a companion in the latter city, and supposing that the human voice would carry so far through the open air, seven and a half minutes would pass before the hail reached the friend in Birmingham. But when the hail is given over the telephone the $110\frac{1}{2}$ miles between the two cities are traversed in the $\frac{1}{560}$ part of a second.

A TRIUMPH OF TELEPHONY

Opening the New York-Chicago Line. Dr. A. Graham Bell speaking from New York to Chicago upon the occasion of the opening of this 800 miles trunk line, October 18th, 1892.

But as the air-waves are translated at the transmitter into electrical waves to fly along the wire they must not interfere with one another as they travel. In other words, they must not tumble over one another, so to speak, or get in one another's way. Although some 50,000 or more such waves are sent out during a single minute, each wave has a distinctive shape. They are just as different from one another as the waves of the sea. These differences in form, as well as the distances between them, must be faithfully preserved and conserved during the journey over the wire, because, if not, they will be indistinguishable at the opposite end of the line. It is not a question of sending out one simple current, but perhaps as many as 120,000 different and tiny currents during the minute. Reaching the receiver each of these electrical waves has to be reconverted into its relative sound wave, which agitates the air sufficiently as to affect the ear and thereby enable the words to be distinguished.

Another point has to be borne in mind. The problem of articulate speech transmission is not affected by increasing the loudness of the tones. You may yell into the telephone, but the sound at the opposite end is no louder than if you talked quietly and distinctly into the transmitter. The effort, producing the electrical waves which speed along the wire, is the weakest energy it is probably possible to imagine, being merely the amount of power set up by the human voice. These breaths start up the electrical waves, shape them, and time the distance between them, with the result that if the transmitter, line, and receiver are capable of fulfilling their designed functions, the words uttered at the one end will be repeated at the other extremity of the line with absolute clearness and distinctness.

But shall we continue to telephone over wires? During the year 1915 surprising achievements were recorded which foreshadow important and far-reaching developments. The ability to send telegraphic signals through the ether and without the aid of wires stimulated scientists to endeavour to transmit the human voice in a similar manner. Wireless telephony and wireless telegraphy have moved contemporaneously for many years past, and although the greatest successes have so far been placed to the credit of wireless telegraphy, talking through the ether is no longer merely a scientific possibility or even a laboratory achievement. European progress in this field was arrested by the outbreak of hostilities, when we were on the brink of startling exploits in the wireless telephony field, but the American investigators, not being hampered by war, have been able to continue their investigations without difficulty.

The engineers of the Bell Telephone Company evolved a new wireless receiver to catch the human voice. When it was considered to have been perfected sufficiently to warrant tests being made they erected two stations—one at Montauk, Long Island, and the other at Wilmington, Delaware—250 miles distant as the crow flies. No difficulty was encountered in this instance, the voice, readily distinguishable and distinct, being caught with ease. Thereupon the gap was increased to 1,000 miles by setting up another station at St. Simon's Island, Georgia.

Even the 1,000 miles through the ether proved a simple, straightforward matter.

Thereupon it was decided to attempt to talk across the continent. In order to facilitate this experiment the United States Government was approached for permission to use the naval wireless station at Arlington, which is adapted to long-distance work. The receivers were set up at the naval wireless station on Mare Island, California, and Pearl Harbour, Honolulu, Hawaii, while special aerials were erected at other stations within range and connected to the ordinary wireless instruments. Only receivers were set up, the experiment being to ascertain whether the voice would carry two thousand miles or so through the ether.

All arrangements were completed for the trials on September 29th, 1915. At first sentences were spoken out from Arlington. These were readily caught and understood at Mare Island. Intimation of the successful receipt of the message was conveyed by the ordinary telegraph and overland trunk telephone wires. Then Mr. Vail, seated in his sanctum in New York, picked up his telephone transmitter to call to his chief engineer at Mare Island, "Hallo, Carty! This is Mr. Vail!"

The words were carried from New York to Arlington over the trunk telephone wire, and upon reaching the wireless station were re-dispatched automatically into the ether, a special device having been designed for this re-transmission from wire to wireless.

Later came back by telegram a message repeating the words which Mr. Vail had spoken, together with the information that the words had been clearly and distinctly heard upon the wireless receiver. This report decisively proved the possibility of telephoning over a distance of 2,500 miles, using only the ether as the medium of transmission. But this was not the most illuminating feature of the test, because even more remarkable records were reported. A message came from San Diego saying that the conversation through the air had been accurately recorded, while the words were also caught at Darien, on the Isthmus of Panama.

But the seal to the achievement was made by the report of the engineer, who had been sent to Honolulu, stating that he had clearly heard a message sent from the Arlington wireless station, and had even recognised the voice of the speaker, whose name he mentioned. Inquiry substantiated the latter factor. The ability to distinguish and to recognise a human voice after flying for 4,000 miles through space constitutes an unparalleled achievement in wireless telephony. The significance of this latter feat may be better appreciated by stating that the distance between New York and Honolulu is greater than that between New York and London, Paris, and Berlin, and even exceeds the distance between the American city and Petrograd, or even the North Pole.

While war prevented the possibility of carrying out experiments between New York and Europe, sufficient time and facilities were granted to make one test in this direction merely to establish its feasibility or otherwise. To the complete satisfaction of everyone concerned the sounds of the human voice uttered in New York were recorded at the Eiffel Tower wireless station in Paris. Thus the practicability of talking through the ether across the broad Atlantic was satisfactorily demonstrated.

Will wireless telephony supersede the ordinary overhead wire and underground cable systems? For general commercial purposes a vehement negative is expressed by those who have been engaged in the experiments. The fact that the messages may be tapped by anyone possessing wireless receivers within radius is fatal to such a widespread application. Privacy in conversation would be absolutely destroyed. Moreover, the criss-crossing of messages, sent in all directions simultaneously, would be recorded by any instrument tuned to the transmitter from which they were dispatched, and would lead to hopeless confusion. Again, the clerk of the weather possesses the last word in the matter. Some days, and under certain conditions, there would be no reliability or certainty in the receipt of the messages.

It is maintained that wireless telephony will occupy its especial and limited channel of application. It will enable speech to be carried to extremely remote corners of the world, thereby keeping the latter in more intimate touch with civilisation; will be useful to navigation; and, to a certain degree, to navies as well. But no promise of a universal wireless telephone service is held out. It is rather a wonderful achievement of science than a commercial possibility. Wireless communication is in its infancy. The future may bring forth a means whereby selection of messages, and consequently privacy of conversation, may be assured as completely as it is with wires and cables to-day. Who knows?

CHAPTER VIII

The Romance of the Typewriter

How many people would consider it possible for one of the greatest inventions of the latter part of the nineteenth century—one which has wrought a complete change in our complex social and commercial life—to have been brought about by a chance remark during conversation? Yet this was actually the case with the typewriter such as we know to-day, which now forms an indispensable friend to the office, counting-house, and library.

The typewriter has wrought a big change in our social conditions, because it heralded a new and vast field of promise for women, providing them with the means of entering the business world to profitable advantage. Moreover, it contributed in no uncertain manner to the rapid and remarkable expansion of commerce, which has formed such a conspicuous feature of the past few decades of the world's history.

It was the winter of 1866. The Great Lakes of North America were tightly gripped by King Frost, and the maritime traffic of the port of Milwaukee had settled down to its six months' hibernation. Naturally, under these conditions, the official duties of the Collector of Customs for the port were not exacting. As a matter of fact, the post was somewhat of a sinecure during the winter months in those days, and it is not surprising that the official was able to concern himself with another business.

At the time to which I refer the seat of Customs was occupied by Mr. C. Latham Sholes. His auxiliary concern was a printing business, and he was also a typical western editor of the period. For many years he and another good citizen of Milwaukee, Mr. Samuel Soule, had been firm friends. This was not surprising, seeing that Soule was a fellow-craftsman, who, however, combined farming with printing, and who had achieved a certain local reputation for his inventive ability. In the course of their trade these two men bound books—cash books, ledgers, and such-like—for their commercial brothers. But these books were notable for one circumstance. The pages were not numbered, this duty being undertaken by the purchaser with pen or pencil.

Sholes and Soule frequently commented upon the shortcomings of this method which led to mistakes and confusion among those men of commerce who lacked method and organisation. One day Sholes happened to mention to Soule that it would be an inestimable boon if the books could be sold with the pages already numbered in printed characters. Certainly this might have been carried out, but it would have entailed setting each number separately for its relative page, while the method would have been so costly that no one would have paid the price for the privilege of buying a book with numbered pages. If it only could be done by a machine!

Sholes's remarks set Soule thinking. He went home, and within a short time had prepared a rough sketch of a machine with which serial numbering might be carried out. He returned to Sholes with the idea, and the two, putting their heads together, effected certain improvements. When they were satisfied with the idea they repaired to a mechanic's workshop in the city and completed arrangements for the manufacture of the parts and their assembling together.

But Sholes and Soule speedily discovered that the building of such a machine which should do its work infallibly bristled with unexpected difficulties. So soon as one was overcome another appeared. Now and again they were baffled by a formidable perplexity. It was only by altering this and re-shaping that piece that progress was achieved. One day, however, they were brought to a complete stop by a difficulty of this nature. Strive how they might, they did not appear to be able to overcome it. They were completely balked.

Now it so happened that in this particular workshop another man was at work upon a device for a different purpose. Mr. Carlos Glidden, whose father owned a highly prosperous ironmonger's shop in Ohio, had gone up into Wisconsin, attracted by farming. While working with the plough he conceived the idea for an improved appliance for carrying out this work, which he described as a "mechanical spader." He committed his ideas to paper and then went to Milwaukee to find someone able to build it. He chanced upon the mechanic who was engaged upon the numbering machine. Glidden was wrestling with his "spader," and being an ingenious, hardworking young fellow, an acquaintanceship sprang up between the three toilers. Now and again they would discuss each other's work in a general sort of way, and thus a mutual interest in their inventions ripened.

On the day when Sholes and Soule were brought to a dead stop by the unexpected suddenly looming up, and failing to solve the problem themselves, they enlisted Glidden's assistance. The latter abandoned his " spader " and went over to the numbering machine. The idea was explained to him, together with the purposes for which it was being built. The expenditure of so much time and trouble over a machine merely for numbering the blank pages of office books consecutively apparently did not impress Glidden very deeply, because when the situation had been described he commented :

" Why don't you try to make a machine which will write letters instead of figures only ? "

It was an innocent remark, to which scant attention was paid at the moment, the successful completion of the numbering machine being the absorbing occupation. Now and again the suggestion was repeated, with the result that in a short while the three men seriously began to reflect as to whether the apparently impossible task of writing mechanically could be achieved. But the numbering machine and the "spader" were slowly advanced, and the letter-writing machine became almost forgotten in the excitement.

One day, in the following spring, Glidden happened to pick up a paper containing an article reprinted from a London periodical, describing a new machine called the "pterotype," meaning winged type, which had been devised by John Pratt, an American who was then living in London, and with which it was possible to write in printed letters at a higher speed than one could write by hand with the pen. It was not merely an inventor's boast, because the circumstance had been proved by actual demonstration. In addition to publishing the article in a complete form, the American paper published an editorial comment, pointing out the great advantages of writing letters by mechanical agency, the benefits it would bestow upon mankind, and the huge fortune that would certainly accrue to the first man who successfully solved the problem.

Glidden handed the paper on to Sholes, who was a keen thinker and possessed of a vivid imagination. The more he thought about the editorial suggestion, and the more he studied the description of Pratt's invention, the more strongly he felt convinced of the accuracy of the editor's opinion that wealth could be won in this direction. Sholes himself was not a mechanical man, but he decided to attack the issue. As Glidden had first suggested a machine for writing letters he was requested to enter the task, while Soule was also invited to participate.

The three men discussed the project enthusiastically, and suggestion after suggestion was advanced, to be threshed out by mutual criticism. Glidden, who was a man of fertile ideas, thought out a number of devices whereby the desired end might be achieved, as also did Soule. But it was found that the suggestions of the last-named were more practical and were preferred. By the time the idea had been reduced to the sketch stage it was found that the projected machine comprised the general suggestions of Glidden, the details of the mechanism as outlined by Soule, with the general principles which were to be fulfilled advanced by Sholes. In all their consultations and discussions the writing machine patented by Pratt formed the general basis for argument and criticism, so that their ultimate machine was directly the result of the influence exerted by Pratt.

Like all great inventions which have consummated a silent revolution, the typewriter is not the product of a single brain. The idea of being able to write letters by means of a machine is probably as old as the art of printing from movable types. As Gutenberg's handicraft swept through Europe, it is only logical to suppose that one or two brilliant minds wondered vaguely whether the idea could not be adapted to letter-writing, especially in view of the imperfect writing implements which were the vogue of those days. But the exigencies of commerce in those times were readily satisfied, with the consequence that any thoughts of achieving this end were probably abandoned as soon as they occurred to fertile and creative minds.

Public attention for the first time appears to have been drawn to the possibility of superseding the laborious process of writing by hand two hundred years ago. Those were the days when the quill pen reigned supreme; when even the steel pen, much less the fountain-pen, and the leaden pencil were beyond contemplation. But a well-known British engineer, Henry Mill, aspired to change all this, because, on January 7th, 1714, he received legal protection from the British Patent Office for a "new and useful invention" comprising a machine which he "had brought to perfection at great paines and expence" intended " for the impressing or transcribing of letters singly or progressively one after another as in writing, whereby all writings whatsoever may be engrossed in paper or parchment as neat and exact as not to be distinguished from print."

The aims of the inventor and the purpose of his machine as described, point clearly to the typewriter. But, unfortunately, nothing further concerning this pioneer effort in writing by machinery is known, because the secret of the process appears to have died with the designer. At all events, no drawings of any description, nor even further illuminating particulars, have ever been obtainable. But there is no reason to doubt the bona-fide character of Mill's claim, because he was generally recognised as being an engineering genius. Moreover, his idea appears to have been of slender significance and to have failed to arouse general interest, because there was no contemporary stimulation of other minds in this particular field, as is the general result of patenting something which is entirely new and novel.

Under these circumstances it is not surprising that more than a century elapsed before any other man is known to have wrestled with the project. Doubtless several persons attacked the problem during the interregnum, but found the difficulties which arose to be so complex and insurmountable that they considered the realisation of such a dream as wildly impossible. At all events, with one or two exceptions, no trace of similar experiments are preserved.

But in 1829 the first typewriter of which there is any authentic knowledge was not only designed, but built. Its creator was an American, William

Austin Burt, a resident of Detroit, and whose name, although but slightly known in connection with the typewriter, is preserved in connection with the invention of the solar compass. In 1829 he was granted a patent by the American authorities for a letter-writing machine, which was described as a "typographer," the language of the day in which printing was generally described as typography, naturally facilitating the evolution of a generic title for the machine. The device was of very rough build, but it worked. The model, together with complete and comprehensive details of the invention, were filed at Washington, but unfortunately the model, which appears to be the only typewriter which Burt ever built, together with all the details, perished in the flames when the Patent Office at Washington was burned out in 1836.

The coming of the steel pen seems to have prompted more energetic attack upon the solution of the problem of writing by mechanical means, and a decided forward impulse was imparted by the "ktypographic machine or pen," which was devised by a French inventor, Xavier Pogrin, of Marseilles, and for which he received a French patent in 1833. This machine introduced for the first time one or two of the details and principles of the modern typewriter, and for this reason is of more than passing interest. For instance, the method of mounting the type upon a bar, which is the characteristic of the modern machine, was incorporated. Another point, although it worked in the reverse manner, was the ability to write in two directions—that is, across the paper from left to right, moving the paper forwards, and then returning to the left to commence the next line. But Pogrin, instead of moving the paper at the end of the line, moved the body of the machine over the writing material. This movement in the two directions, however, was carried out by means of rack and pawl, and alignment was assured by means of guides.

The evolution of a means of writing with type received a fresh impetus during the 'forties, but, strange to say, this was not from motives of facilitating commercial correspondence, but was due to activity in two totally different fields. The telegraph was becoming appreciated, and was gradually extending in all directions. The development of this system of communication ultimately brought about the necessity to translate the telegraphic symbols or code into Roman characters. Sir Alexander Bain and Sir Charles Wheatstone individually grappled with the issue and conspicuous success was achieved. They undoubtedly contributed material assistance to the evolution of the typewriter, although the influence may not have been so obvious then as it is from the current survey of the problem. In the first telegraph printers a coiled strip of narrow paper was used, the words thus being recorded in a long continuous line, in much the same way as with the modern tape machine. At first only Roman capitals were used, as in the machine designed by Sir Charles Wheatstone in 1851; but in the succeeding machine, built five years later, both capital and small letters could be printed, and this was the first typewriter in which this end was consummated.

The second field comprised the work of those inventors who were striving to ameliorate the conditions of the blind, and in such a manner that they could read and write at will. At the York meeting of the British Association for the Advancement of Science, held in 1844, Mr. Littledale, who was a resident of that city, exhibited a machine for embossing characters. His types were made of wood and arranged in a slide. The requisite letter was brought to the required position upon the paper, and the smart tap of a hammer caused the character to be embossed. Then the paper moved along to allow the next character to be recorded.

Six years later another inventor, Mr. G. A. Hughes, governor of the Manchester Blind Asylum, animated by the motives which had prompted Mr. Littledale, produced a machine for accomplishing a similar end —to enable those deprived of sight to "record their thoughts on paper." It was designed essentially for embossing purposes, but subsequently legible characters or printing was carried out by the use of carbon paper. For this machine the inventor was awarded medals at the Great Exhibitions of 1851 and of 1862.

The news of the success achieved by Littledale and Hughes in the interests of the blind appear to have reached America, because we find Mr. Alfred E. Beach, of New York, diligently evolving typewriters for the blind and giving embossed characters. In one of the early machines devised by Beach, in which the type-bars were revived, the latter were disposed in a circle, and each, when depressed, came to the common centre. In the later machine a more complicated system was introduced, the levers being double and in pairs, so as to form a die. The pair of levers of the desired character rose to the common centre, and, gripping the paper, embossed the character.

About the same time as Beach was carrying out his experiments, a French inventor, Pierre Foucault, who was a pupil of the Institution for the Blind in Paris, devised a machine with a curved keyboard which printed raised letters very successfully. When the letter had been embossed the paper was moved forward a space to receive the succeeding character, the action being effected by aid of a rack and pawl. This machine received a greater meed of attention than many of its contemporaries, several being built for blind institutions, and it attracted considerable attention at the Hyde Park Exhibition of 1851.

Although the idea of writing mechanically was somewhat diverted from its original sphere between the years 1833 and 1860 by the introduction of the telegraph and laudable attempts to improve the facilities for the convenience of the blind, attention was recalled to the business side of the idea by the work of another American investigator, Charles Thurber, of Worcester, Massachusetts, who devised an ingenious typewriter in 1843. This machine, although slow in operation, proved capable of doing very satisfactory work. It is worthy of notice because it embodied a feature to be found in every modern machine—letter spacing by automatic means through the movement of the paper carrier. Although this typewriter was more promising than any of its predecessors, it failed to arouse commercial enthusiasm. Only one machine survives as a monument to Thurber's genius, and this is now carefully preserved in an American museum.

THE FIRST COMMERCIAL TYPEWRITER

Built by the American gun-makers, Remington & Sons, to the designs of the machine brought to them by C. L. Sholes & James, Densmore, in 1874.

THE LATEST REMINGTON MODEL

The principle is the same, but even a glance at the pictures shows what vast improvements have been made.

In 1857 another forward stride was recorded through the ingenuity of Dr. S. W. Francis, a wealthy medical practitioner residing in New York. In this typewriter a piano-hammer action was introduced, the types, which were nested in a circle, being thrown to the common centre. The machine executed some very fine work, but was too intricate to command any commercial value. But it brought the realisation of Henry Mill's dream a decided step farther, because, in a crude form, many of the essential features of the typewriter were embodied, such as the travelling carriage moving to and fro from line-end to line-end and placed above the type, together with the alarm bell to indicate approach to the end of the line, blank key for spacing, and other minor details.

But the turning-point in the evolution of the typewriter undoubtedly came with Pratt's machine, owing to its subsequent influence upon Sholes, Soule, and Glidden. Several of these were built, one of the improved types being preserved in the South Kensington Museum. In this machine, built in 1866, there are thirty-six symbols, corresponding to the capital letters and numerals, mounted in three rows of twelve each upon a vertical type roller. This arrangement, it may be mentioned, gave rise to the type-wheel classification, indicating those typewriters in which the type is mounted upon a wheel. The paper was inserted together with a sheet of carbon paper. When the key was depressed the corresponding letter upon the type-wheel was brought into position, and a smart tap imparted by a hammer striking through the carbon left an imprint of the letter upon the paper. Upon the release of the key the paper moved forward automatically a sufficient distance to receive the next letter. Instead of spacing between words by means of a special space-key, the paper movement for this purpose was obtained by partially depressing any one key.

The appearance of the Pratt typewriter stimulated the inventive activities of Sholes, Soule, and Glidden, and we have seen how they drew up their plans for the first machine. The trio lost no time in building a machine to their ideas, and by September, 1867, the first typewriter according to their designs was completed. It was extremely crude, and for the most part was designed by Soule. The types were pivoted in a circle, as in the case of preceding models, and included the letter spacer. But it proved a success, and the three men were highly satisfied with their first effort. It printed only capitals, but it worked accurately and with commendable speed. The inventors were so delighted with their handiwork that they sent letters to several of their friends as a concrete illustration of what they had done.

One of these letters happened to be sent to a retired printer and editor, Mr. James Densmore, who was then living at Meadville, Pennsylvania. His journalistic experience enabled him to realise the importance of the invention, and his receipt of this letter proved to be the turning-point in the fortunes of the invention, because, without seeing the machine, but merely its work, his enthusiasm and imagination were aroused. He offered to purchase an interest in the invention by reimbursing the three men for all the money they had expended upon it up to that time. Densmore was an essentially practical and business-like man, which was well known to the trio, and doubtless with visions of wealth untold they accepted with alacrity his offer to pilot the idea through its troublous early days.

It was March, 1868, before Densmore saw the actual machine, despite the fact that he had already advanced the money for his interest some six months previously. When it came into his hands he point-blank declared it to be of no commercial value whatever as then built, but was useful as showing the idea of being able to write letters in type. This was a decided set-back to the diligent toilers, and their faces fell. But Densmore reassured them, demonstrated the defects, and suggested how they might be overcome. This emphatic declaration appears to have disgusted Soule and Glidden, because they retired from the enterprise, and there and then declined to have any more to do with it. However, Sholes was a more determined type of man, and, also having a business turn of mind, recognised the justice of Densmore's criticisms.

Sholes stuck to the machine, and at Densmore's suggestion built another, incorporating certain improvements which his colleague considered essential. Then a third machine was taken in hand to overcome some other defect. And so it went on, model after model being built, each representing a certain improvement upon its predecessor. Sholes found Densmore an exacting partner, but there was no alternative. When a model had been built Densmore turned it over to some person to operate it, and to submit it to the use which it would experience in the average office. The result was inevitable: each machine broke down from some cause or other. Then the succeeding model had the weakness in the preceding machine remedied, only to have another defect become manifest, and which likewise necessitated a further model. This treatment was a sore tax upon Sholes, but Densmore was implacable. Before it could possibly be placed upon the market the machine must be made reliable. Sholes grew more and more disgusted with the invention as model after model was built, and almost regretted the day that he had ever been prompted to attempt to devise a machine which would write type.

In fact, it is probable that Sholes would have abandoned the idea had it not been for the insistence of Densmore, whose enthusiasm remained unabated, notwithstanding the exasperating difficulties which loomed up and required solution. As Sholes discovered afterwards, it was essentially the common sense of Densmore which saved the invention from lapsing among the many others which had gone before.

Once the two men came to an argument, but Densmore emphatically declared that he would abandon the whole thing unless it was carried to such a degree of perfection that anyone might use it, and with an immunity from breakdown. Densmore's unrelenting attitude won the day.

Five years slipped by in this work of perfection, during which period Sholes built about thirty successive models. Then Densmore concluded that it had been brought to the stage when it might be safely handed over to a competent firm for manufacture, and thus be introduced to the commercial world.

The question arose as to which was the best firm to carry out its manufacture. It involved, from the character of the mechanism, expert mechanical skill. Ruminating upon this aspect of the question, Densmore finally came to the conclusion that a firm which specialised in the making of rifles and small firearms constituted the most promising field, because the mechanics were expert in fitting intricate and delicate mechanism. He concluded that the firm of E. Remington and Sons, which occupied the pre-eminent position in the United States in this realm of industry, would probably be the most satisfactory concern to which to entrust its production, if he could prevail upon the firm to take it up.

Apparently Densmore was somewhat dubious of his commercial persuasiveness, because he suggested that a friend of long standing, Mr. G. W. N. Yost, should accompany him upon his momentous mission. Yost was an experienced man of business and possessed valuable, if not hypnotic, talking powers. The idea meeting with approval, Densmore and Yost sallied forth to try to complete a deal with the gunmakers.

But the task proved to be one of extreme delicacy, and almost taxed the fluency of Yost. The Remington firm was not particularly impressed with the model; it was still far from being sufficiently perfect to be considered a commercial enterprise. The gunmakers at first declined to have anything to do with it. But Yost and Densmore were not to be denied. They talked and talked, and at last the gunmakers yielded to their persuasion. They decided to undertake its manufacture, and, moreover, undertook to devote the whole of their resources towards the improvement of the machine.

That was in the early months of 1873. When the

Remington experts took the machine in hand they found it almost hopeless in its original condition. They embarked upon entirely new designs. These improvements entailed considerable time, patience, and expense, with the result that 1874 was well advanced before the "Remington typewriter," as it was called after the manufacturing firm, and one which to-day is known throughout the world, was ready for the market. The first commercial model was christened "No. 1," and now is colloquially known as "the ancestor of writing machines."

But the appearance of the typewriter was not hailed with such enthusiasm by the business community as had been anticipated. The Remington firm were engaged with its manufacture purely and simply: they had practically nothing to do with its sale. A separate entity was established for this purpose, Densmore and Yost combining to this end. Samples of work carried out by the machine were scattered like leaves far and wide, and an attempt to rivet attention upon the new time- and labour-saver for the office was made at the Centennial Exhibition held at Philadelphia in 1876, where, by the way, Bell was striving with might and main to induce the public to regard his telephone favourably.

The public would have nothing to do with the typewriter. In the first place, it printed only in capital letters. This limitation is somewhat remarkable, seeing that Wheatstone's typewriter for the rapid printing of telegrams, which had been invented ten years previously and which used both capital and small letters—upper and lower case—was well known.

The first improvement was effected through the ingenuity of Lucien Crandall, who introduced the carriage-shifting device, which paved the way for the invention of Byron A. Brooks, a professor of higher mathematics, who conceived the idea of mounting the upper and lower case form of each character upon the one lever, either of which could be brought into use by the manipulation of a shift-key. When the two characters of each letter were introduced the machine began to appeal more strongly to the public.

However, the early days of the typewriter were extremely chequered, and the young invention experienced many vicissitudes. At times it seemed as if it would inevitably succumb to public apathy. Even Yost's commercial persuasiveness failed. Successive managements of the selling agency which was founded to dispose of the machines, under varying styles of Densmore and Yost, could not make headway with it. Densmore was the first to retire from the field. Ultimately Yost, who clung to the invention, associated himself with two other partners, D. R. Locke and J. H. Bates, the firm being known as Locke, Yost and Bates.

Even this trio could not force the machine upon the commercial world. Some important factor was missing—either imagination, skill, or art—in salesmanship. The one thing which did develop was the accumulation of debt, which presently reached such a figure as to render all likelihood of retrieving the money sunk in the enterprise impossible, much less the winning of a fortune. The financial side of the problem was investigated thoroughly. There was a critical meeting, at which the whole situation was threshed out.

The upshot of this conclave was a reorganisation of the selling end of the enterprise. There was an American firm, Fairbanks and Company, which had the entrée to the commercial world from end to end of the country, and who possessed a magnificent organisation. Surely they would be able to force the typewriter upon the market! They were approached, and ultimately satisfactory terms were adjusted. Under the ægis of Fairbanks and Company, the machine certainly made headway, but progress was exasperatingly slow. At last the Remington Company terminated the arrangement, and decided to assume the selling end of the business themselves.

A typewriter department was created and organised under Mr. C. W. Seaman. The sales grew steadily, if not sensationally. The experience of direct dealing with the selling world convinced Mr. Seaman that enterprise and acumen would convert the invention, which up to now had been struggling desperately for recognition, into a world-wide success. But in order to achieve this end, he realised that a reversion to the former selling system would be requisite. He evolved a proposal, and upon suggesting it to two friends, who were accepted business men of the first water, a new scheme was established. These two friends, Messrs. Wyckoff and Benedict, agreed with the outlook and situation as revealed by Mr. Seaman, and decided to form an alliance. In this manner was formed the now well-known firm of Wyckoff, Seamans and Benedict, and they took over the sole selling agency for the Remington typewriter.

This move proved to be the turning-point in the chequered fortunes of the invention. These three men were full of enthusiasm and initiative, combined with stern business qualities, and they infused a force into the work which hitherto had been lacking. The sales went ahead with astonishing rapidity. The task was prosecuted with such diligence and energy that within two years another change was deemed advisable. Up to 1886 the manufacture of the typewriter had been regarded somewhat in the character of a side issue by the gunmaking firm. Now it was decided to incorporate it as a separate business, because thereby it would become easier to carry out any improvements in slight details taught by experience, as well as the embodiment of any new features which time and commercial developments might render necessary. In other words, it became as incumbent to devote as much whole-hearted care and attention to the machine and its parts as were given to the guns. Messrs. Wyckoff, Seamans and Benedict thereupon approached the firm of Remington and Sons, and explained their proposal. They offered to purchase the young invention, together with all the plant which had been laid down for its production, as well as all contracts and other arrangements. That is to say, they were ready to buy out the typewriter department lock, stock, and barrel, and thus relieve the gunmakers of any further interest or liabilities connected therewith.

The gunmaking organisation agreed to the proposal. With the financial and other assistance of a few friends, the Remington Standard Manufacturing Company was founded. The name Remington was continued by arrangement, inasmuch as by now it had become familiar to the commercial world. This severance of the typewriter section of the business fortunately proved wise, because the young invention escaped the financial and other disasters which shook the old-established gunmaking firm to its foundations, and which otherwise would have seriously jeopardised the fate of the typewriter.

But while such desperate efforts to install the Remington in the commercial world were in progress, it was subjected to attacks from other directions. Yost, after the firm of Locke, Yost and Bates were deprived of the sole selling agency for the machine, feared that he would lose all interest in a new business to which he had devoted so much time, effort, and money. Accordingly, he endeavoured to evolve and perfect a machine would would become a powerful rival. He was confronted with a superhuman task, inasmuch as the patents protecting the Remington were so comprehensive as to render it difficult to build a machine without infringing the pioneer claims somewhere or other.

Yost strove desperately to consummate his ambition, but was foiled. The machine which was built to his designs was noticeable for having a double keyboard—capital and small letters respectively—thereby dispensing with the shift-key. In reality, the double keyboard idea was forced upon him because it was impossible to use the two characters for each type-bar without infringing the shift-key patent. Ultimately, Yost discovered that it was virtually impossible to build a machine which would be completely clear of the Remington patents, and therefore he applied for a licence to build and vend his own machine. The privileges which were extended to him were severely limited, and reacted somewhat against the success of his efforts for some years.

Although the Remington was experiencing such a stern uphill fight against commercial conservatism and prejudice, its chequered career did not affect the enthusiasm of other inventors who aspired to woo fortune with the typewriter. Two men, James B. Hammond and Lucien Crandall, endeavoured to steer clear of the Remington patents by introducing type-wheels. This precipitated an unexpected *dénouement*. The machine which had been invented by Pratt in 1866, while he was resident in London, and which was quaintly described as the "pterotype," attracted attention. The inventor, realising its shortcomings, devoted considerable labour and expense upon improvements. Finally, he applied to the United States Government for patent protection. But, to his dismay, he discovered that Hammond and Crandall disputed his claims with their respective type-wheel principles, and he was threatened with litigation. For a time there was a complete deadlock, but at last the situation was overcome by Pratt conceding Hammond's claim to prior invention, while Crandall proceeded with his patent, which, he maintained, differed from both that of Pratt and Hammond.

The typewriter of to-day may be divided into three broad classes, according to the principle of operation. There is the type-bar machine, such as the Remington, and this is the principle adopted in the greater proportion of machines of the times. Then there is the index machine, in which there is an index plate and a pointer. The letter to be printed is brought into position over the printing point, and then pressed upon the paper by means of a knob. This type of machine is very simple, occupies very little space, and is light in weight. But it is slow in operation, and has virtually disappeared from the commercial world. Finally, there is the type-wheel machine founded upon the principles of the Pratt and Hammond typewriters, in which the type is mounted, or cut upon the face or rim of a wheel, which is revolved by depressing the key to bring the required letter to the printing point and then smartly depressed upon the paper. The Hammond and Blickensderfer machines offer probably the most illuminating examples of this system.

But it is the type-bar machine which reigns supreme to-day. It is not only fast in working, but being of substantial design and construction, is able to stand up to the hardest work. The typewriter industry underwent a tremendous impetus upon the expiry of the Remington master patents, which, up to that time, thwarted competition. At the moment discussion rages around the respective advantages and disadvantages of the single keyboard with shift-key and the double keyboard. But, generally considered, it is probable that the shift-key system has the greatest number of supporters.

Some idea of the arduous task with which the pioneers were confronted in the early days, and an illuminating impression of the widespread success and popularity of the typewriter at the moment, may be gathered from the fact that the total sales of the Remington typewriter during the first ten years of its history—1874 to 1884—scarcely equalled the sales of a single month at the present time. In order to demonstrate the present magnitude of the business, which has only been in existence a little more than forty years, it may be stated that over 500,000 stenographers and typists to-day owe their living to the Remington typewriter. In the United States alone the Company finds situations for approximately 100,000 typists per annum, whose salaries aggregate over £1,200,000 per year. Other countries can point to similar results upon a corresponding scale.

In the early days extreme difficulty was experienced in rendering the single selling agency remunerative. But to-day selling establishments are maintained in 738 cities throughout the world, each of which is a fully equipped organisation, and of which total 324 are in Europe and 240 in North America. The department, which passed through many vicissitudes some thirty years ago with indifferent results, now provides employment for 7,500 persons, exclusive of the vast number of mechanics and others who are engaged in the actual manufacture of the machine.

The extent to which the typewriter has conquered the world may be gathered from the fact that the Remington Company furnishes 1,100 different keyboards, this total including keyboards for writing in 156 different languages and dialects. And this concerns only the pioneer and parent company. If the figures for the typewriter industry as a whole could be marshalled, it would afford an impressive insight to the manner in which commerce, industry, and even private life has been revolutionised by an invention of contemporary history.

CHAPTER IX

The Steam Turbine

ALTHOUGH the comparatively new science of electricity is making tremendous headway and is working a wonderful revolution, we must not forget that the present is essentially the age of steam. Indeed, in many countries electricity is the servant of steam, because without the latter it would be almost impossible to produce the former.

Incidentally the advance of electricity has in itself precipitated a striking change in the methods of using steam, more particularly for the generation of the "juice," as the invisible current is facetiously called. This revolutionary steam-raising force is the turbine.

We are apt to regard the steam turbine as a wonder of the past quarter of a century, but, as a matter of fact, it represents the oldest method of harnessing steam to perform some useful task of which we know. It antedated the steam-engine, with which we are most familiar—the latter representing essentially the activity and inventiveness of Newcomen and Watt—by centuries. The Egyptian philosopher Hero describes a steam-driven turbine in his book on "Pneumatics," which was written over a hundred years before the dawn of the Christian era. This, however, according to the facts which have been handed down to us, was nothing more than a demonstration apparatus, the steam being induced to rotate a sphere or globe mounted on trunnions by the impingement of the vapour jet upon the atmosphere.

Whatever was accomplished with such a device as described by Hero, history does not relate. Apparently a further seventeen hundred years sped by before the idea underwent a serious revival. Then an Italian experimenter named Branca devised a little machine comprising a horizontal wheel, around the periphery of which vanes were set. A jet of steam was brought to bear upon these vanes and caused the wheel to revolve. The power thus obtained in this primitive manner was utilised to drive a small mill for grinding drugs. This represents, so far as we are able to ascertain, the first commercial attempt to use the steam turbine.

While the steam turbine was the first steam-engine to be invented, it was the last type of steam-engine to be developed. From time to time brilliant minds attacked the problem, but they failed to make any decisive headway. Certainly they contributed meagre results of any constructive value. It was not until the early 'eighties of the nineteenth century that a distinct advance was made. In fact, the steam turbine may be said to have been reborn, inasmuch as this latest advance, which ushered in the era of this type of engine, was as different from all previous efforts in this field as is the modern fighting ship from the prehistoric oar-propelled galley.

No doubt the trend of thought which has been centred for centuries upon the turbine or rotary engine became diverted into another channel through the achievement of Newcomen and Watt. Their work gave the world a new means of generating power which changed completely our conditions of industry and locomotion, inasmuch as their ideas culminated in Stephenson's invention of the locomotive and of the steamship. Yet the rotary engine has always possessed an indescribable fascination for inventors, comparable with the search for perpetual motion; and, up to the dawn of the 'eighties of the past century, just about as much success was recorded in the former as in the latter field of thought and experiment.

The rotary engine differs from its rival very radically. In the steam-engine devised by Newcomen and Watt, and the fundamental features of which remain to this day, the steam is admitted into a cylinder in which moves a piston. The pressure, or expansive properties of the steam, drive the piston back to the limit of its travel in the cylinder. Attached to this moving piston is a long rod, the piston-rod, the opposite end of which is attached to a crank, set at right angles to the piston-rod. The movement of the piston communicated through the rod revolves the crankshaft, to which a flywheel, acting as a reservoir of energy, is mounted. From this flywheel the power may be distributed to other machinery through a suitable medium, such as gearing, belt, chain, or by friction. When the piston has reached the limit of its backward travel steam is admitted behind it, thereby driving it forward. This action not only gives another boost to the crank and flywheel, but serves to drive out of the cylinder the steam which was first admitted and has completed its work. A fresh supply of steam enters the cylinder at its forward end, driving the piston back once more, this alternate introduction of

Photo by courtesy of the Parsons Marine Steam Turbine Co., Ltd.

THE FIRST PARSONS TURBINE STEAMER

The little "Turbinia" making 35 knots—39¾ miles per hour.

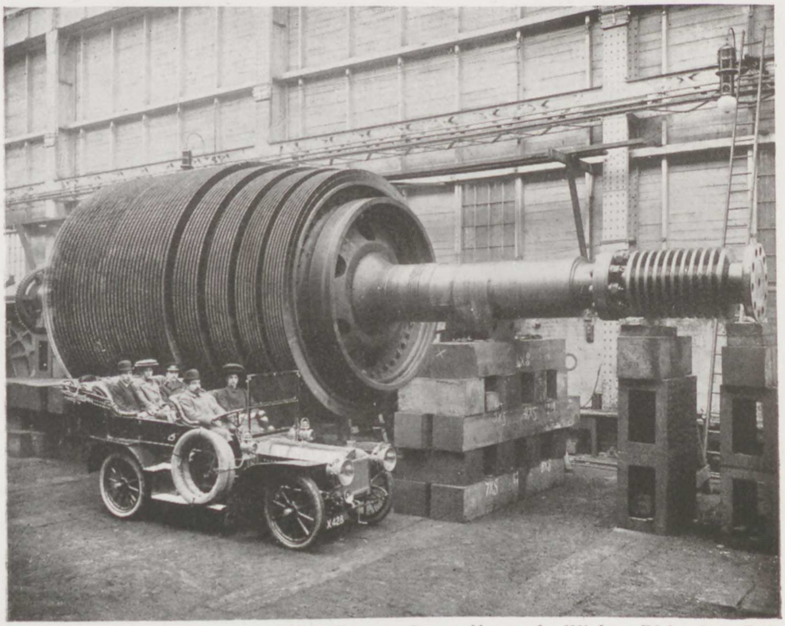


Photo: Messrs. Swan, Hunter & Wigham-Richardson, Ltd.

A GIANT PARSONS TURBINE

The low pressure rotor, fully bladed, of the S.S. "Mauretania." Note size as compared with motor-car.

the steam at either end causing the piston to move to and fro rhythmically.

The piston itself has an oscillating or reciprocating motion, but this becomes converted into rotary motion through the intervention of the crankshaft. The details of construction may undergo certain modification according to requirements. For instance, in the locomotive there is no flywheel in the generally accepted sense of the term, inasmuch as the driving-wheels are mounted upon the crankshaft. Yet the driving-wheels are really flywheels, and impel the locomotive forward by friction with the rail. Such constitutes the broad principles of the steam-engine's operations, which from the to-and-fro motion of the piston has led to its being generically described as the reciprocating engine.

In the rotary engine the idea is to apply the steam in such a manner as to give a direct rotary motion. There are no cranks, pistons, or piston-rods. What would be the crankshaft in the reciprocating engine becomes a straight driving-shaft in this instance. Rows of vanes or blades are mounted in rings upon it, and the steam playing upon these projections causes the blades to rotate. As these blades are fixed to the shaft they drag the latter round with them. At first sight it appears to be a simple, straightforward undertaking to cause a shaft to revolve in this manner; but, as a matter of fact, the question is attended with innumerable difficulties of a highly technical and scientific character. These problems, coupled with a lack of essential knowledge concerning the scientific side of the subject, militated against the early experimenters.

Public appreciation of the steam turbine has been fostered by reason of the achievements which have been recorded therewith in connection with steam navigation. But, in reality, the propulsion of mercantile and fighting ships by this means represents a minor feature, the wonderful records set up therewith notwithstanding. The turbine was first brought into use for the generation of electricity, and it is in this realm that its widest successes have been attained.

The re-invention of the rotary engine, such as we know to-day, really dates from 1883. In that year the Honourable Charles Algernon Parsons, the fourth son of the Earl of Rosse, became a partner in the well-known Tyneside engineering firm of Messrs. Clark and Chapman. For some years previous the new partner had been considering the possibility of improving the steam-engine. Indeed, he had invented a new type of rotary steam-engine, somewhat reminiscent in its operation to the rotary motor which has figured in aviation ; but this engine, while admittedly ingenious, was considered to be too complicated for everyday use, although a certain number were built.

When he entered his new sphere of operations he decided to commence the construction of a new type of rotary engine, the lines of which he had been nursing for some time in his mind, and in which cylinders and pistons, together with their attendant mechanism, were to be eliminated. It was completed in 1884, and its designed purpose was to drive a small dynamo for the supply of electric current for lighting. While admitted to be an experimental model, it represented the first practical engine of this character. and proved capable of doing good work.

As a matter of fact, it was put into service and for several years was in constant operation, running at 18,000 revolutions per minute, at which it gave out 10 horse-power. It was directly coupled to the dynamo which gave 5 electrical horse-power. When its term of utility was considered to have been completed, it was presented to the South Kensington Museum, where it now enjoys an honoured resting-place beside the pioneer achievements of other inventors in various fields.

The success of this first turbine was responsible for the construction of another, which was placed upon the small steamer *Earl Percy*, to supply current for sixty electric lights upon the vessel. This plant continued to run successfully and satisfactorily until the loss of the ship at sea a few years ago.

The invention appeared at the period when the electric lighting of vessels was being taken in hand seriously, the advantages of this system of illumination being so overwhelmingly superior to the oil lamps which were then the vogue. As the turbine had established its value for the generating of the current, it is not surprising that the demand for installations upon board ship commenced to grow, and, in fact, constituted the most favoured field of application. But its suitability for land stations was not overlooked, and many plants for such work were laid down, including equipments for electrically lighting Lincoln's Inn Hall and New Scotland Yard in the metropolis.

As the new system grew in favour the inventor found the demand upon his time become more and more exacting. At last he came to the conclusion that it would be necessary, in the interests of the welfare of the infant he had raised, to devote his whole time, thought, and energies to its perfection. Consequently, in 1889 he severed his connection with the firm of which he had become a partner barely six years before. He established small works at Heaton, outside Newcastle, where he undertook the construction of turbines and dynamos. Incidentally it may be mentioned, that in setting out upon his own account in this manner he not only established a further business which was destined to attain considerable dimensions, but he also created a new source of wealth by originating and developing a new industry.

The decision was partly influenced by another far-reaching move which was then rapidly maturing. A number of leaders of commerce of Newcastle and neighbourhood foresaw the demand that was certain to arise in the area for the purchase of electric current for lighting and power. The teeming yards and shops which contribute to the prosperity of the city upon the Tyne offered attractive virgin soil for the supply of the "juice" upon an extensive scale, and for which the demand would steadily increase. These hard-headed, perspicacious business pioneers had heard about, and had watched, the new invention which, although still young, was rapidly maturing.

When, therefore, the Newcastle and District Electric Lighting Company, Limited, was brought into existence, it was decided to equip the power station with the Parsons' turbine. This represented the first application of the new steam-engine to the public supply of electricity, a field which the inventor had always maintained to hold out the most attractive possibilities. As he had confidently expected, the initial effort proved a pronounced success, and further installations were carried out upon these lines in other parts of the country.

Meantime, needless to say, the size and output of the engines had been steadily and persistently increasing, until a unit of 200 horse-power, with a working speed of 4,800 revolutions per minute, and consuming 16 pounds of steam per indicated horse-power per hour, was produced. This engine differed from its predecessors in one salient respect. It was the first condensing turbine engine which had been brought to the practical stage.

Although the turbine was forging ahead somewhat rapidly, new and unexpected difficulties were continually cropping up, and, one by one, had to be subjugated. For instance, in the very early days, the steam turbine, although it was warmly espoused, was somewhat vehemently assailed because it proved a veritable glutton for steam. This drawback was maintained to be fatal in many quarters, but the inventor, once he had surmounted the initial difficulties of design, attacked the steam-eating problem with a view to rendering it more economical and comparative in this respect with the reciprocating engine, which naturally, in view of the century or more which had been expended upon its development, had been brought to a high degree of perfection.

As the call for larger and more powerful turbines arose, the steam-eating question appeared to solve itself automatically, because it was speedily discovered that the turbine is far easier to build in large sizes, with a reasonable steam consumption, than it is in small units. In other words, as the output of the turbine increased, the consumption of steam per horse per hour decreased.

Some idea of the rapid growth of the new invention, once it had established its possibilities, may be gathered from the fact that in 1903, twenty years after the first engine appeared, units of 9,000 horse-power were being built, not only in this country but on the Continent as well. From 10 to 9,000 horse-power was an impressive advance during the short span of two decades, and such progress offered a fair index of the revolution the new engine was likely to achieve.

The land stations yielding technical information which proved that the turbine was capable of holding its own generally, and was even then threatening to supersede the reciprocating engine in certain fields, the idea of applying the new principle to the propulsion of ships naturally arose. The subject was discussed by the Honourable C. A. Parsons and his influential friends, and, there being no logical reason why the success recorded on land should not be repeated upon the sea, it was decided to make the experiment and to determine the future in this connection from actual trials.

To this end, in 1894 a special syndicate was formed —The Marine Steam Turbine Company, Limited. It was composed of the inventor and several other gentlemen who had every confidence in the new steam-engine, and among the chief members who extended assistance may be mentioned the Earl of Rosse, C. J. Leyland, George Clayton, Norman C. Cookson, H. C. Harvey, John B. Simpson, A. A. Campbell Swinton, G. G. Stoney, and, of course, the inventor himself.

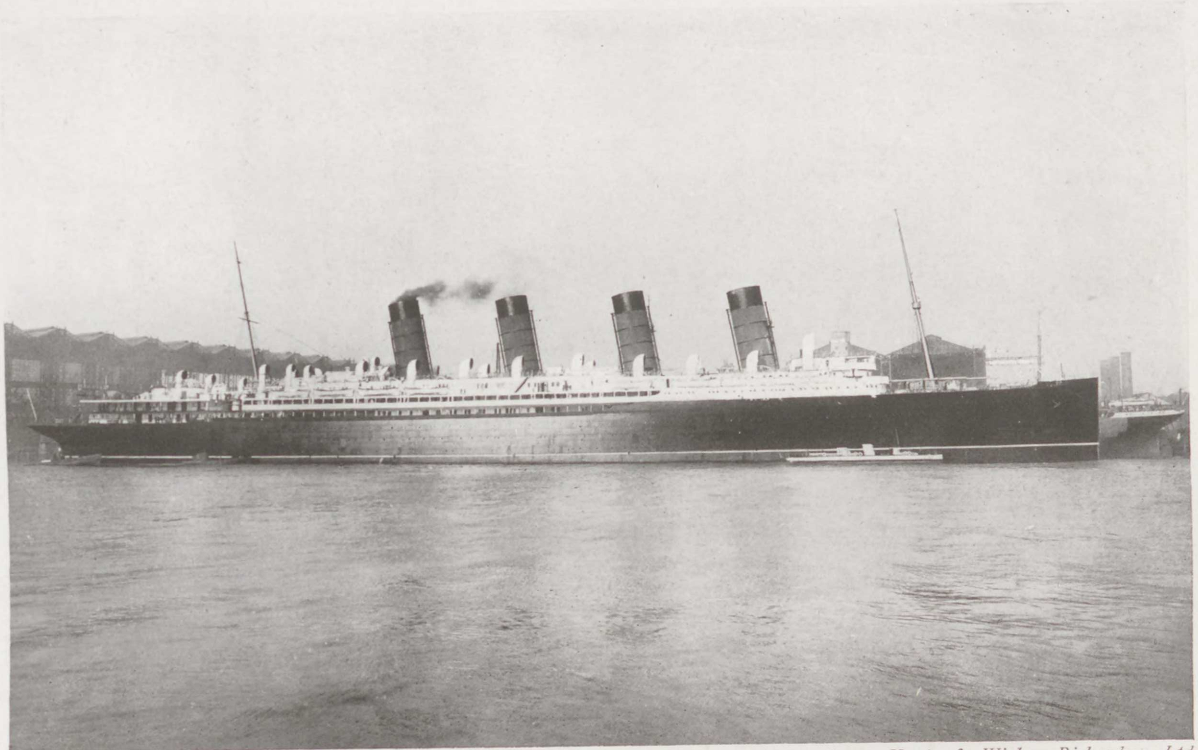


Photo: Messrs. Swan, Hunter & Wigham-Richardson, Ltd.

A COMPARISON OF PROGRESS

The pioneer "Turbinia" lying beside the transatlantic greyhound, "Mauretania," whose Parsons turbines develop 70,000 horse-power.

When the idea of driving a ship by turbines was first mooted, the inventor was disposed to shoulder the whole of the responsibility and financial burden himself. It was plunging into the unknown and failure might be recorded. When discussing the project, the Honourable C. A. Parsons declared that the only successful means by which the turbine could be driven home as an engine for propelling ships was to embark upon a vessel which could give a higher speed upon the water than had ever been attained before. Speed would attract widespread attention, not only among the general public but in the technical world as well. The experiment was bound to involve a considerable outlay, because anything of such a radical character in the realm of navigation is inevitably expensive, involving the construction of a special vessel and in this instance of machinery as well.

However, his friends decided to stand in with him. In the event of failure the individual loss would not be pronounced; while if it succeeded each was certain to meet with an adequate reward. The foundation of the syndicate furnished the sinews of war for the construction of the vessel and its machinery, and the inventor hoped that upon its trials the new boat would show a speed of 32 knots. The vessel, christened *Turbinia*, was completed in the autumn of 1894. It measured 100 feet in length, 9 feet beam, and when ready for the trials displaced 44½ tons. It was fitted with a single turbine driving a single propeller-shaft.

The first tests were made upon November 14th, 1894, but they were not satisfactory. The vessel was brought back to the works, and certain modifications were made. The next trial was no more successful—that is, so far as the speed attained was concerned. It seemed as if the turbine were doomed to failure as a rival to the reciprocating engine upon the seas. Propellers of varying form and design were used and subjected to searching tests. These trials were spread over a period of two years, during which time 31 sea speed tests were carried out. But it seemed impossible to squeeze more than 19¾ knots out of the tiny craft.

During this period a vast volume of new knowledge was being acquired. It must be remembered that this was all pioneer work. The inventor had to find out things as he progressed, and when baffled he had to discover the source of the difficulty and its remedy. Such work in connection with the propulsion of ships is long and tedious. Each difficulty as it cropped up was probed scientifically, so that a conclusive reason for this or that might be forthcoming. The accumulation of knowledge during these two years proved of incalculable value. Had the inventor achieved success at the first attempt the majority, if not all, of the problems which he was forced to negotiate would have had to have been settled in later years.

At last, upon the conclusion of a particularly searching scientific investigation concerning the propeller—experiments which have contributed very materially to the science of ship propulsion—the inventor came to the conclusion that a single turbine, propeller-shaft, and propellers would never meet the situation. In this manner the speed could not be raised above 20 knots. Forthwith the boat was taken home, and the existing machinery was removed. In its place three turbines were installed, each driving a shaft, and each of the latter carrying three propellers.

When re-engined the vessel was sent to sea once more, and the results achieved startled even those who had been financing the experiments, realising what there was at stake. From time to time further runs were made with various propellers, the idea being to discover the highest speed which could be attained. But the speeds were fairly consistent, ranging around 32 knots. This exceeded anything previously attained upon the sea, but it was finally eclipsed when the little boat issued from one of her runs with the maximum speed of 34.5 knots—about 39 miles an hour—to her credit. This was in February, 1896.

Such results naturally stirred the young company. The expectations of the inventor had been fully realised. While such a high speed was possibly unnecessary from the commercial point of view, still it was demanded for certain specific purposes, such as the propulsion of torpedo boats. Accordingly it was decided to introduce the turbine to the notice of the Admiralty; but as the great Naval Review at Spithead, in honour of Queen Victoria's Diamond Jubilee, was about to be celebrated, it was decided to send the little vessel to Spithead. The *Turbinia*, with the inventor aboard, made the journey from the Tyne to the review, and assumed a position among the visiting vessels which were kept to their allotted stations by a patrol of destroyers.

Up to this time the achievements of the *Turbinia* in regard to speed had not been generally communicated to the world, although well known to those interested in the enterprise. But her turn of speed was revealed to one and all in a dramatic manner and with all the force of a thunder-clap. It was the day of the review, and the lines between the warships were cleared for the passage of the Royal yacht. Suddenly, by some means or other, a little boat, of which no notice had hitherto been taken, was observed to have strayed from her position, and was in one of the lanes. How she got there no one knew. But the moment she was detected one of the torpedo destroyers hurried up with the idea of escorting her outside the prohibited area. The torpedo boat fussed up, but directly her purpose was divined by the little boat the latter appeared to become imbued with life, turned, and fled away at a merry pace with the patrol in hot pursuit. The torpedo destroyer put on every ounce of speed, but instead of the intruder being overhauled, she romped away, rapidly increasing the speed between pursued and pursuer. Other torpedo destroyers took up the chase, including some of the fastest craft in the Navy, but even they had the mortification of seeing themselves being left behind.

The spirited chase, which was seen by one and all, aroused widespread and excited interest. What was the little craft which had raced away, apparently so easily, from the fastest boats in the Navy? Inquiries were made, and it was found to be a vessel of which no one had ever heard—the *Turbinia*. How had it been possible for her to show such a wonderful turn of speed? What was the reason?

Naturally, the unassuming little craft attracted all eyes, both of the general public who witnessed the episode and of the naval authorities. The upshot of the matter was that more information regarding the *Turbinia* was demanded. And it was supplied. All the papers throughout the world devoted columns to detailed descriptions of the new boat and the wonderful new steam-engine with which she was equipped. The *Turbinia* and her turbines leaped from obscurity to the forefront of animated interest, and became the one topic of discussion.

After such a sensational appearance it is not surprising that the Admiralty turned their attention to the invention, the upshot of which was the award of a contract to the Marine Steam Turbine Company, Limited, for the construction and engines of a new torpedo boat destroyer of the same dimensions as the 30-knot boats then in service, but of one knot higher speed. The authorities called for a guaranteed speed of 31 knots, at which the coal consumption was not to exceed 2½ pounds of coal per indicated horse-power per hour. While the *Viper*—as this destroyer was called—was in hand, a contract for similar turbines for the sister ship *Cobra* was also awarded to the company. Both vessels easily complied with the official requirements, the *Viper* exceeding the contract by 5 knots—she notched the highest speed, 36 knots or 40½ miles an hour, which had ever been achieved on the water—and at 31 knots was easily within the specified coal consumption by about ⅛ pound of coal. Unfortunately, both these vessels were lost, the *Viper* running upon the rocks skirting the Island of Alderney during a fog, while the *Cobra* mysteriously foundered with the whole of her crew during a storm which burst while she was running from the Tyne to Portsmouth.

The turbine not being contributory in the slightest degree to either of these disasters, the Admiralty placed further contracts for this machinery for vessels under construction. These culminated in the fitting out of the *Dreadnought* in 1906, which was the first battleship to be driven by turbines.

The success with naval vessels proving so highly satisfactory, it was decided to ascertain the suitability of the system for the mercantile marine. The conditions were somewhat different, because very high speeds were not desirable. It was Captain John Williamson, of Glasgow, who acted as the pioneer in this field, by ordering turbine engines for the new vessel, *King Edward*, which was built for him in 1901 for service upon the Clyde. This vessel, measuring 250 feet in length by 30 feet beam, and drawing about 6 feet of water, was similarly equipped with three sets of turbines, one, the high pressure, being placed in the centre, with a low-pressure turbine on either side. On the central shaft only one propeller is mounted, but the wing shafts each carry two propellers. In addition, there is a special turbine for reversing. This vessel attained a maximum speed of 20½ knots upon her trial trip.

A year later another vessel, *Queen Alexandra*, was built for the same owner. She was of slightly greater dimensions but similarly engined, although the turbines develop greater power—sufficient to give a speed of 21½ knots. The success of these two boats led to the adoption of the steam turbine upon the cross-Channel and other similar services.

The invention was also embraced for private steam yachts, the first in this category to be so engined being the *Lorena*, built for an American owner ; upon her trials she exceeded the contract speed by 2 knots. One of the advantages of the steam turbine as compared with its established rival is the saving in space and weight. This was brought home very strikingly in connection with this yacht because it enabled the saloon accommodation to be increased very appreciably over what the originally contemplated reciprocating engines would have given, while there was also a saving of 70 tons in the weight of the machinery.

It is impossible to follow the triumphant progress of the Parsons steam turbine upon the seven seas in the space of a single chapter. But from cross-Channel services to the spanning of the Atlantic was an obvious step. While the first vessel to cross the Atlantic under turbine propulsion was the private steam yacht *Emerald*, the first vessel for public service of this character was the Allan liner *Virginian*. Other lines followed suit in rapid succession, high-water mark being reached with the *Lusitania* and *Mauretania*, wherein huge turbines, developing 68,000 and 70,000 horse-power respectively, were installed. This power exerted through four propeller-shafts and propellers, enabled the greyhounds, 785 feet in length and displacing 38,000 tons, to clip through the water at a maximum speed of 25½ knots.

While the turbine was passing from triumph to triumph on the water, its progress in connection with land operations was fully maintained, and although less impressive from the public point of view, its achievements are equally sensational. The coupling of dynamos or alternating current generators direct to the shaft of the turbines became an accepted practice. Such installations required less space for their accommodation as compared with reciprocating engine alternators of equal power, while there was the additional advantage of less fuel consumption and reduced vibration. Turbo-alternators are the established electric generating combinations throughout the world to-day where electric current has to be generated from coal.

Some years after the Honourable C. A. Parsons had demonstrated the possibilities of the steam turbine, an American inventor, Professor C. G. Curtis, introduced his conception of this type of rotary engine to the world. At first it was built in the horizontal form, in which feature it followed its British prototype, but afterwards it was designed upon vertical lines, only to revert finally to the horizontal type. While this turbine has been used upon a limited scale for the propulsion of ships, its greatest province of application has been, and still is, in connection with the generation of electricity. Some of the installations which have been carried out are remarkable for their dimensions and capacity, the largest installation which has been completed up to the moment being of 50,000 horsepower.

The turbo-electric installation has facilitated the task of the electrical engineer to a very significant degree. The rotary engine is extremely compact and occupies very much less space than its reciprocating rival. While this may not be a serious factor in

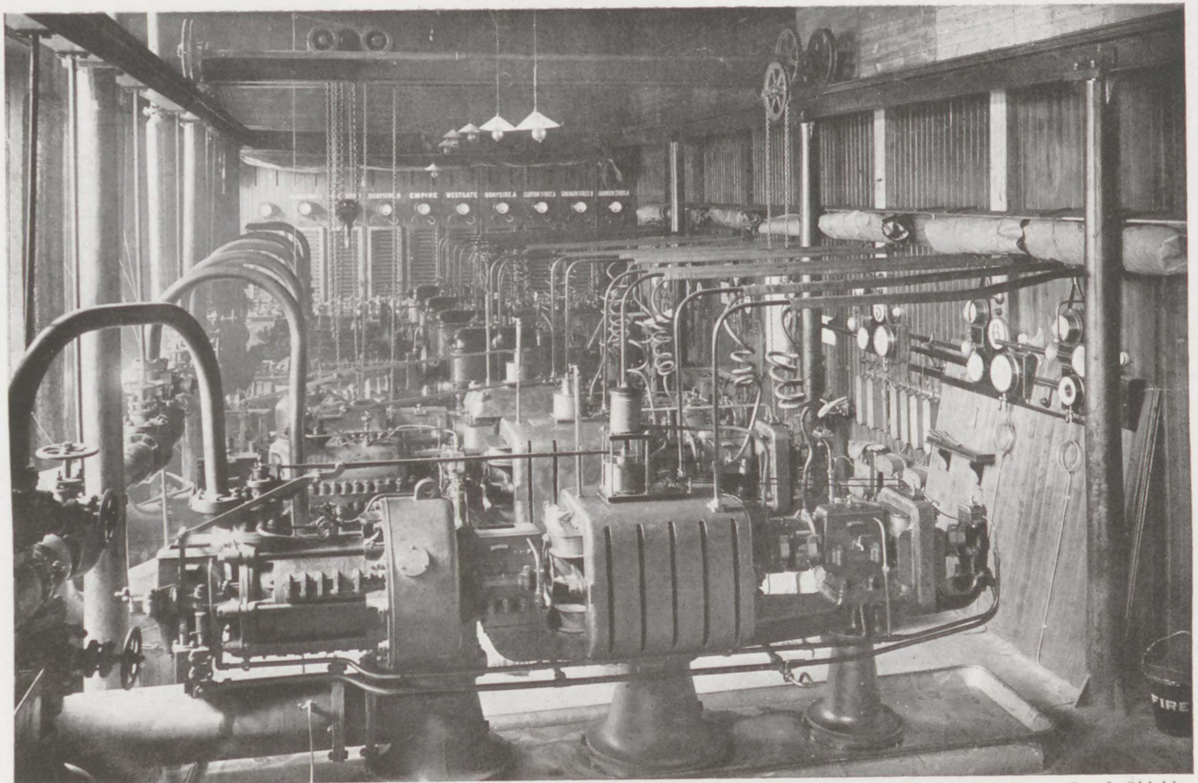


Photo: W. Parry, South Shields.

THE FIRST PARSONS TURBO-ELECTRIC GENERATING STATION

The photograph shows the early type of Parsens turbine, installed by the Newcastle and District Electric Lighting Company. Although this turbine has revolutionised marine propulsion, it was first employed for the economical generation of electricity, in which field it is still achieving startling conquests.

the case of small installations, yet it becomes of far-reaching import when large plants are being laid down. In fact, the extent to which power may be compressed within a limited space by the adoption of the turbine as compared with a reciprocating engine of equal power is astonishing. It is these features which have contributed to the design and construction of units of such power as would never be attempted with the older type of prime mover.

As the science of applied electricity, in its ever-conquering advance, took up the question of generating electricity from water-power, either by harnessing stupendous falls such as those of Niagara or the flow of rivers such as the Mississippi and others, the question of the best ways and means to turn this power to advantage in the most effective, economical, and simplest manner naturally arose. In the earliest days the water-wheel constituted the obvious means of driving the electric generator. But the water-wheel in its familiar form, whether undershot or overshot, had its limitations of application, which were sharply defined. Still, it constituted an ideal foundation for further thought and development which has culminated to-day in the water turbine.

The water turbine does not differ from its steam contemporary in its fundamental features. It is a rotary engine driven by the falling water instead of by steam. An American inventor made the first decisive step in this direction, and, curiously enough, he occupied himself with the problem with water as the driving force about the same time that the Hon. C. A. Parsons centred his thoughts upon the steam turbine. Pelton, the American in question, conceived the idea of placing small cups around the periphery of a wheel mounted upon the shaft, instead of blades. The idea was found to be practicable, and the Pelton wheel soon sprang into favour. Development followed development rapidly, the greatest measure of attention being devoted to the design of the cups in order to utilise the force of the impinging water to the utmost.

Other inventors adhered to the vane or blade system, virtually adapting the steam turbine principle to water-power, thereby producing a strict water turbine. Both methods have a considerable vogue, and many impressive installations have been brought into operation. The Falls of Niagara have been harnessed, a moiety of the tremendous aggregate energy—estimated to be 7,000,000 horse-power—there running to waste being harnessed to generate current for lighting, heating, and power for miles around. Waterfalls have been tamed in various other countries—even in these islands—for a similar purpose. Factories, railways, and tramways run on current derived in this manner; while miles of streets and scores of thousands of buildings are lighted by electricity which has been obtained by taming a wild waterfall or swiftly rushing stream or river.

One of the largest hydro-electric stations which has been brought into operation during recent times is that at Keokuk, in the Mississippi Valley. A huge barrage, 4,278 feet in length, has been thrown across the full width of the Father of American rivers, and near one bank there is a huge power house, 1,718 feet in length by 132 feet in width, housing thirty hydro-electric units, each having a capacity of 7,500 kilowatts, representing an aggregate of 225,000 kilowatts operated by the running water. The Mississippi is generally described as the untamable waterway, but in this instance it has been trapped very effectively, and is contributing very significantly to the amenities of the communities scattered far and wide throughout the valley.

While the turbine has made a phenomenal advance during the brief span of its present existence, and may seem to be threatening its reciprocating rival, there is little danger of the latter being driven into oblivion. Indeed, in certain phases of application, such as commercial navigation, the ideal steam-engine of the moment comprises a combination of the two methods of operation. The steam upon issuing from the turbines is far from being absolutely "spent." It still possesses sufficient life to perform further useful work, and so is passed to the reciprocating engine, where the last ounce of energy is wrung out of it.

CHAPTER X

The Coming of Electric Lighting

THE wonderful and far-reaching applications of electric lighting which have been carried out during the past few years somewhat prevent us realising the fact that the possibility of utilising electricity in such a manner as to produce illumination was determined over a century ago. Indeed this discovery, if such it may be called, was made about the same time as coal-gas was being forced to the front as a lighting medium.

It was the eminent British scientist, Sir Humphry Davy, who first demonstrated the feasibility of electric lighting. But it was essentially a laboratory experiment, and was carried out for the enlightenment of his scientific colleagues at the Royal Institution about 1809.

The apparatus employed by Davy, while of simple design, was most elaborate. He took 2,000 primary batteries and coupled them together. The mammoth battery was necessary to supply the sufficiently powerful current which was required for the experiment. The negative and positive waves were led from the battery to two charcoal rods. Davy demonstrated that when these two electrically charged rods were brought together and then moved a little distance apart the current continued to jump across the gap, and in so doing gave a brilliant light, which was described as the electric arc.

The phenomenon is capable of simple explanation. The electric current heats up the points of the carbon to such an extreme degree as to render the charcoal incandescent. Moreover, the space created between the two opposing points by moving the rods apart—across which the current leaps—becomes charged with a kind of cloud or vapour. In reality this gap becomes filled with an enormous number of extremely minute particles of carbon detached from the two charcoal rods. This microscopic carbon dust is maintained in a condition of extreme incandescence, and thus forms an apparent flame.

As may be supposed, Davy's fascinating experiment and demonstration aroused intense scientific interest ; but at that time it was impossible to develop its utilisation in such a manner as to make wide public appeal. The fact that batteries constituted the only known means of supplying the requisite current was an insuperable obstacle. Davy's work, however, was of inestimable value from the scientific point of view, and even at that date he contributed information concerning arc-lighting which otherwise would have had to be discovered in later years before such a system of illumination could have aspired to win popular favour.

Although the particles of carbon are detached from the rods and continue the whole while the current is passing, Davy showed that the wearing away is not equal for the two rods. The erosion, or burning away of the rod fed with positive electricity, proceeds twice as rapidly as the decomposition of the negative rod. Moreover, under the passage of the current the ends of the two rods undergo considerable change. That of the negative rod assumes a point, while the extremity of the positive corrodes to form a crater-like hollow. Now, as these points burn, the length of the gap across which the current has to leap increases until at last it becomes so wide as to be beyond the capacity of the current. Accordingly, owing to the break in the circuit, illumination dies down. But the light can be re-established merely by bringing the two extremities into contact once more and then separating them by a short distance as before. The act of bringing the charcoal rods together to form electrical contact is known as "striking" the arc, and the flame continues all the while the gap between the two is kept fairly constant. To fulfil this latter necessity, however, a means had to be devised to feed the arcs together, thus preserving the length of the gap.

While Humphry Davy's fascinating experiment induced his contemporaries to carry out further investigations along the line of research he had indicated, progress was conspicuously slow. Indeed, there were periods which seem to have been totally unproductive. It remained for another eminent British scientist to impart a new boost to thought and experiment in this channel. This was Michael Faraday, who twenty years later, while he was director of the Royal Institution, discovered and set forth the principle of electro-magnetic induction. Faraday not only talked but did things, in which he differed from many pioneers. He built a machine wherein his principles were ocularly demonstrated, and thus produced the first primitive dynamo, or, as it was then termed, magneto-electric machine.

As may be supposed, the diversion of inventive activity into a new and more promising field brought forth a bounteous crop of improvements. Each individual effort may not have represented a great advance in the light of current knowledge, but in those days, when very little was known about electricity—it was an infant science—each contribution was considered a distinct forward stride.

Generally speaking, progress was comparatively rapid, and in 1845 electric arc lighting underwent a decisive revival. A British inventor, Thomas Wright, of London, devised a means of automatically adjusting the carbons, so that the gap between them was kept fairly constant at the required distance. It was acknowledged to be a fearsome-looking apparatus, but it sufficed to indicate that the hope of electric lighting becoming reckoned as an accomplished fact was very much alive. The automatic feeding of the carbons appears to have attracted the greatest measure of attention during this period, because numerous devices to this end appeared in rapid succession, culminating in the arrangements of Serrin, Duboscq, and Professor F. H. Holmes. Serrin introduced a method of feeding the carbons which represented a distinct advance upon any preceding devices; in fact, the main features thereof were subsequently revived and introduced into arc lamps of the contemporary era of this form of illumination. Duboscq contrived a distinct form of arc lighting, while Professor Holmes, in 1858, designed and built a powerful magnetic electric machine upon the broad principles laid down years before by Faraday. This apparatus was driven by a steam engine, and, as may be imagined, a current surpassing in power anything previously attempted was obtained.

Now that a means of generating the electricity upon a sufficiently large scale, and a reliable arc lamp, had been brought to success, commercial application of the idea was inevitable. But the field in which it was exploited differed very materially from what one might have expected. It was not taken in hand for the lighting of streets, houses, factories, or general buildings; it was used for lighting the highways of the sea for the guidance of mariners. At the time, Professor Faraday—who first gave the principles underlying the dynamo to the world—was scientific adviser to the Trinity House Brethren, the authority responsible for the lighthouse protection of the coasts of England. He saw the electro-magnetic machine devised by Professor Holmes, and he was so impressed therewith that he strongly urged the lighthouse authorities to test the new illumination, to ascertain in a practical manner its suitability for this field of duty. His suggestion was accepted, and forthwith a complete installation was mounted in the South Foreland lighthouse, which thus ranks as the first lighthouse in the world in which electric lighting was adopted.

It was a supreme test; and to ensure that the new idea should receive as fair a chance as was possible, the installation was built with every care, because the responsibility of the light at this corner of the coast was fully appreciated. The lamp devised by Duboscq was first installed; but in 1862 a lamp invented by Professor Holmes was set in position. With this installation many interesting investigations were carried out, and on a clear night the warning light, owing to its elevation upon the lofty cliff, was clearly distinguishable from the galleries of the French lighthouses upon the opposite side of the Straits of Dover. Subsequently, owing to the success of this initial experiment, electric lighting was adopted at the old Dungeness lighthouse, while it was also put into operation at the Cape Hêve light in France and at other places.

The work of Professor Holmes and his contemporaries may be said to represent the first practical era in electric lighting. While the electro-magnetic machine, as built by this investigator, was successful for isolated installations, it was impossible for the supply of current in bulk from central points or stations.

The whole issue was changed by the invention of the dynamo, as we know it to-day, in 1866 and 1867, and especially by the contribution of the Belgian inventor, Z. T. Gramme, resident in Paris, in 1870. Contemporary investigators had attacked this problem, but it remained for Gramme to make the most decisive forward step, because his invention brought the arc-light within the realms of commercial exploitation, and, indeed, ushered in the modern electric lighting epoch.

Nevertheless, a few years passed before the arc-light appeared upon the market. It was brought to the forefront again by Monsieur Jablochkoff, whose light became known as the "Jablochkoff Candle." It appeared in 1876, and instantly attracted attention because of its extreme simplicity, which led to its extensive use. This candle comprised two sticks of carbon, each about one-sixth of an inch in diameter, set parallel and separated by a thin insulating barrier formed of kaolin porcelain. At the top the two carbons were connected by a carbon paste to strike the arc. When the current, supplied from a Gramme machine, was switched on, this paste connection was readily heated up to such a degree as to volatilise.

While this action was taking place the extremities of the carbon rods were also becoming heated to a sufficient degree, so that, when the paste connection had disappeared, the arc could be maintained across the gap between the two rods, and also the intervening porcelain insulator. The latter was burned away at the same speed as the carbons themselves, so that the arc was maintained without difficulty until the carbons had been burned out.

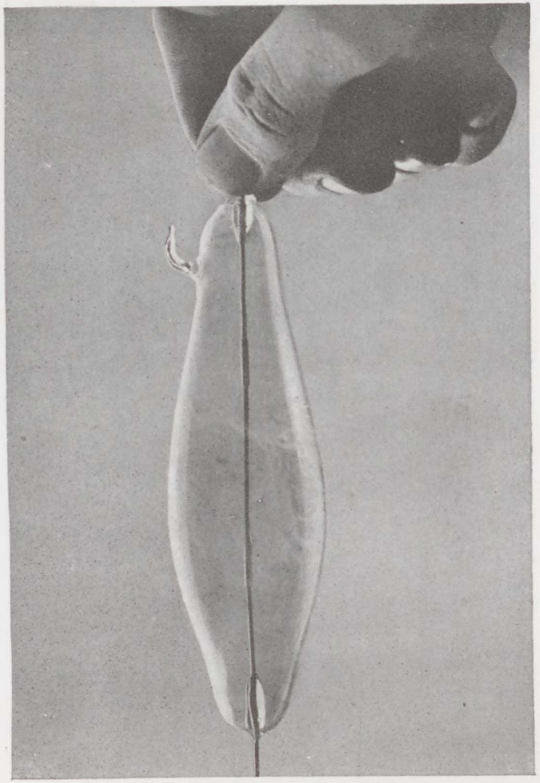
But, as already explained, with two carbons of equal dimensions the positive rod is consumed about twice as rapidly as the negative rod. To overcome this inequality in consumption carbons of varying diameter were first used, though subsequently alternating current was employed, which enabled carbons of one diameter to be used. The light emitted from this electric "candle," while not very brilliant, was far superior to that given by gas-burners of the period. Consequently the Jablochkoff candles had quite an exciting vogue in Europe, several thousands being sold. Electric arc-lighting was introduced thereby to London, the exterior of the old Gaiety Theatre in the Strand being one of the first places to be illuminated in this manner. The candles, however, suffered from a comparatively short life, the average duration of the light being from 1½ to 2 hours. When they had burned out new carbons had to be introduced by hand. With a view to reducing this disadvantage as far as possible, an improvement—comprising a device for holding several candles—was made, in which successive lighting of the candles was carried out by an attendant with the aid of a switch.

The reign of the Jablochkoff candle was summarily cut short, in the main, by the appearance of the arc lamp devised by Charles F. Brush, an American inventor. This was very similar in its general features to that in use to-day. The following year—1878—this experimenter also perfected the series arc dynamo. These two improvements brought the electric arc lamp well within the realms of practical use, and as a result of vigorous campaigning and enterprise to initiate the public into the advantages of the new illumination, great headway was made throughout the world. Developments followed in such rapid succession, and the contributions of the men of science were so skilfully applied, that the invention became firmly planted among the community, especially as the light was so vastly superior to gas, no matter from what point of view it was considered.

But as time passed the problem of electric illumination assumed a new significance. The arc-lamp's sphere of utility was somewhat limited, and the need for some other form of electric lighting became felt more and more acutely. The arc-lamp was excellent for the brilliant illumination of streets, open spaces, and interiors of spacious buildings, but was not adapted to the illumination of the average shop or the suburban home. Here gas reigned supreme, and at the time this form of consumption constituted an excellent sheet-anchor for the gas-producing interests. If electric lighting were to be rendered a menace to the supremacy of its rival in this field, a revolutionary development was essential. The light would need to be free from all complexity, of less candle-power, require no attention, dispense with the daily renewal of the carbons, and impose no more tax upon the intelligence of the user than the gas. Moreover, in order to be able to compete more effectively with the coal rival, electricity would have to be furnished upon a similar basis and at a comparative price, because in such matters the pocket governs the decision of the prospective customer.

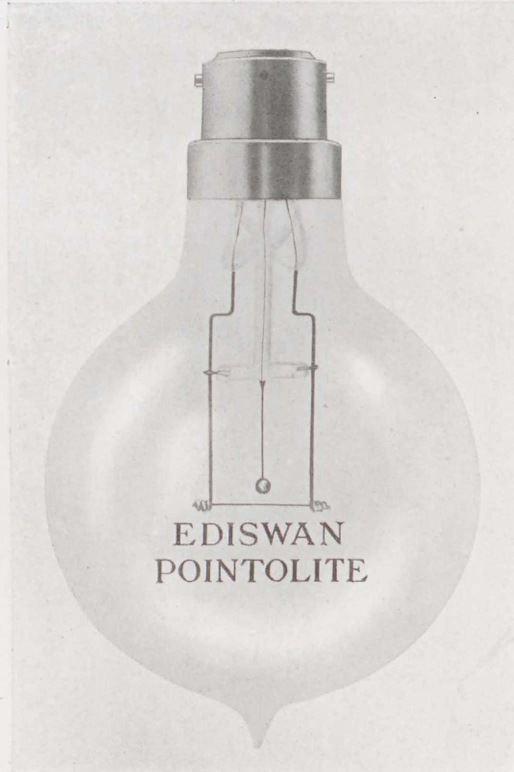
This demand precipitated what became known as the effort to "subdivide the light," and it was a problem which attracted many industrious scientists and investigators. One and all attacked the question contemporaneously and, for the most part, unknown to each other. First and foremost in this widely distributed band was Mr.—afterwards Sir—Joseph Wilson Swan, F.R.S., a native of Sunderland, and whose name has been identified with many and various notable inventions, particularly in connection with photography.

During the year 1845 Swan, then a boy of seventeen, saw the experiment carried out by Staite, in which a thin platino-iridium wire was raised to a condition of incandescence by the electric current. That experiment set the youngster thinking. If wire could be made white hot in that manner and emit a bright light from its incandescence, why should it not be possible to harness the piece of wire in a glass bulb, and thus adapt the discovery to a commercial



THE FIRST INCANDESCENT ELECTRIC LAMP

Invented by Sir Joseph Swan.



THE EDISWAN POINTOLITE

The latest development in Electric Light.

Photos by courtesy of the Edison and Swan United Electric Light Co., Ltd.

use? Forthwith he started experimenting for himself, and then he recognised that the question was by no means so simple to solve as it appeared at first sight.

However, he was not to be turned from his line of investigation, and recurring difficulties only served to spur him on. Every conceivable medium capable of being raised to incandescence under the passage of the electric current was tested, and a tangible idea of the laborious character of this particular quest may be gathered from the fact that fifteen years were expended upon the work before a practical incandescent lamp was obtained. As a result of the hundreds of experiments which were made Mr. Swan discovered that a fine thread of carbon of high resistance, when enclosed in a glass bulb from which the air had been exhausted, gave the most successful results, and he demonstrated the success of his experiments to a few favoured friends.

This was in 1860, and the carbon incandescent lamp did not differ very materially from that of to-day. The fundamental principle was the same, except that instead of the carbon being placed in the form of a loop within a pear-shaped bulb, it was carried through from end to end of an attenuated cigar-shaped tube. In the first successful lamps the carbon filament comprised a strip of carbonised paper, and the lamp of this type is shown in the photograph facing page 224.

This initial success prompted Swan to pursue his investigations. With the cigar-shaped tube he had succeeded in obtaining incandescent electric lighting. Now the issue was resolved into the modification of this principle into a form which should command commercial approval. As a result of further experiment, he evolved an improved filament consisting of carbonised parchmentised cotton-thread, and this he shaped in a loop capable of being placed within a pear-shaped, spherical, or any other form of bulb, and wherein, owing to the terminals of the loops coming side by side in the holder, it was possible to introduce the lamp in any way—hanging or standing vertically, at an angle, or in any other desired position—into an electric wiring circuit.

Swan carried out his work in the secrecy of his laboratory. He apparently did not court publicity, and little seems to have leaked out concerning what he was doing or what he had accomplished. In 1877—seventeen years after Swan had solved the problem—the American inventor, Thomas A. Edison, attacked the question. He certainly appears to have been entirely ignorant of what the British inventor had already accomplished, or if he had heard of his work, he invested the reports with very slender significance, owing to the little information thereof which was available, because he commenced his researches with carbonised paper, to discover what Swan had ascertained long before. Edison, however, was facilitated by an invention which had been introduced to the world in 1865, and which had been denied to Swan in his earlier days. This was the Sprengel air-pump, which offered a means to obtain an extremely high vacuum in a glass globe. This air-pump induced Edison to revert to the carbonised cotton thread which Swan had used, and which Edison also determined to be the most promising substance for this purpose after testing a wide range of other materials.

Edison achieved success with this filament in October, 1879, but in February of the same year Swan had startled the world by exhibiting publicly at a meeting of the Newcastle Chemical Society the lamp which he had made in 1860, the current for which, as in 1860, was obtained from a battery of 50 cells. This exhibition aroused widespread interest, which culminated in Mr. Swan installing lamps of his design to illuminate the rooms of the Newcastle Literary and Philosophic Society. In other words, incandescent electric lighting had been adopted and put into operation in Britain at a day when Edison had not carried his lamp to a laboratory success.

In the meantime, Swan had satisfied himself that the filament would have to be improved, and was struggling with this phase while Edison was still experimenting with the carbonised cotton-thread. Edison, who had found that a piece of bamboo when carbonised, made an excellent filament, created attention by dispatching expeditions to all parts of the world in search of a still better fibre for the purpose. Meantime the British inventor was labouring diligently and silently in his laboratory in another channel altogether, and in which, strange to relate, his American rival likewise turned his thoughts at a later date.

Swan was trying to discover a synthetic substance, which would be equal to the natural fibre. Here he achieved distinct success, because he was the first to evolve and to perfect the squirting process which is now used all over the world in connection with the preparation of the filament. This brought about the first commercial "subdivision of the electric light," because thereby it was rendered possible to produce an artificial fibre, made from cellulose, which subsequently was proved to be the ideal material for the filament. Incidentally it may be mentioned that in consummating this great achievement for incandescent electric lighting Swan also laid the basis of another industry which to-day has reached enormous proportions—the manufacture of artificial silk.

Swan's discovery sealed the commercial success of universal electric illumination, because his later improvements rendered it possible to produce a filament of exceeding fineness and uniformity. Thus a degree of economy which had never before been attainable was reached in the distribution of electricity, which led to the extension of the range of lighting from central supply stations. Consequently Swan is entitled to the distinction of being the father of the modern idea of distributing electricity from central points, in the manner of water and gas.

In 1881 Edison, considering that the conditions were ripe for the exploitation of his discovery in Europe, planned the invasion of Paris and London. The Edison plant was placed near Holborn Viaduct, and the adjacent thoroughfares, together with the City Temple and part of the General Post Office, were electrically illuminated. In the furore which was created Swan appears to have been overlooked, the lamps which he had invented failing to claim pronounced attention. In Paris the Edison installation at the Exhibition created a wild excitement, the American inventor becoming the hero of the hour.

Britain is prone to ignore her own inventors, and in this instance the axiom of the prophet and his

ONE DEVELOPMENT OF ELECTRIC LIGHTING

An Electric Searchlight carried by an American locomotive. The ray enables the driver to see any object, no larger than a man, half a mile away.

own country was once again illustrated very convincingly. But the interests which had supported Mr. Swan were not disposed to tolerate the American march of triumph. The Edison interests received a severe shaking-up, when at the heyday of their sensational advance, by the intervention of litigation. If Swan could not receive the public recognition he deserved spontaneously, then the law must decide to whom the honour is due.

The fight over the claim for the invention of the incandescent electric light was fought stubbornly and bitterly. Thousands of pounds were sunk in trying to prove this and rebutting that. It was not until counsel dived into argument that Britain realised what one of her own sons had contributed to the progress and amenities of the world.

The upshot of this spirited bout in the Law Courts was somewhat unexpected, although perfectly logical under the unusual circumstances which prevailed at the time. Terms were arranged between the two antagonists, who decided to combine forces and thus be in a position to wage war against other claimants.

In this manner was born, in 1883, the Edison and Swan United Electric Light Company, and the lamp placed upon the market was and is still known far and wide as the " Ediswan," a generic title formed by compounding the names of the British and American inventors. But although Swan failed to receive an unassailable distinction in the courts, he obtained it from the foremost scientific body in the world—the Royal Society of Great Britain—by the bestowal of one of its highest honours, the Hughes Medal, which was awarded to Sir Joseph Swan for "his invention of the incandescent electric lamp and various improvements in the practical applications of electricity." Thus was honour satisfied and a British claim to an epoch-marking invention absolutely vindicated.

The carbon incandescent electric lamp revolutionised and popularised electric lighting, not only in Britain but in other parts of the world, to such an extent that gas illumination was threatened with extinction. The latter was revived by the introduction of the Welsbach incandescent mantle. The utilisation of rare earths for bringing about a more brilliant illumination with a lower consumption of gas caused electrical engineers and scientists to wonder whether they might not be impressed in the service of electric lighting to a similar end. There ensued another spirited race among our foremost electrical authorities in this new quest, and one in which, by the way, the British were not lagging, despite their generally believed lack of energy and enterprise. The rare earths were tested one after the other, but the quarry proved extraordinarily elusive. For years it seemed to be a hopeless investigation. At last it was announced that a new filament had been devised—one which was made from the mineral tungsten. The first lamp of this type was given the distinctive name of "tantalum," after the metal which was used for the fabrication of the filament.

The metallic filament lamp, as it became generally described, imparted a revived impetus to electric lighting. What the Welsbach incandescent mantle had done for the pockets of the consumer of gas the new filament was able to do for the pockets of those who preferred electric lighting—reduced the consumption of current and consequently the cost thereof, from 50 per cent. to 70 per cent. By the discovery of the filament lamp gas and electric lighting were once again reduced approximately to level terms.

But the lamp in which the rare earths were directly utilised was one of which great expectations were entertained, but which did not survive the metallic filament incandescent rival. It was of the glow-lamp type, the filament comprising a composition of the oxides of zirconium and yttrium. But this filament suffered from the disadvantage of requiring heating-up before it would conduct electricity. A certain period of time was required for this purpose, fine platinum wire wound round the filament comprising the heating agent. The light emitted by this lamp was a decided improvement upon the carbon incandescent lamp, while the general shape thereof gave it the appearance of being a miniature arc-light. It commanded attention because of its lower consumption of electricity per candle-power, which at first was considered to be more than adequate to counterbalance the few seconds occupied by the preliminary necessity to heat-up the filament by switching on the current. But before the Nernst lamp, as it was called, could be developed, it was excelled by the new arrival which consumed even less electricity per candle-power, and thus it lapsed into obscurity.

The new metallic filament lamp, especially in its high candle-power forms, threatened to usurp the older and well established arc-lamp, even for general lighting purposes. But progress was not stationary even in this field. Improvement after improvement was effected, each of which exerted some decided influence upon this form of illumination. For many years plain carbons were used, the light from which was bluish-white in colour. Subsequently calcium fluoride was combined with the carbon, the light from which is a rich warm orange or rose-coloured tint. Another contribution to the science was that evolved by Professor Steinmetz, who discovered that magnetite, or lodestone, is superior to carbon, its efficiency being twice as great; and this led to what is known as the magnetite arc-lamp.

In describing the incandescent electric lamp, I have related how the filament is placed in a glass bulb from which the air is exhausted. For many years the investigators concentrated their energies upon extracting as much air as possible from the globe. Upon the perfection of the metallic filament lamp the line of research veered round completely. A number of scientists concluded that a far brighter light, with a proportionately lower consumption of electric current, might be obtained if the glass globe were first exhausted of air and then charged with one of the inert gases, of which nitrogen is the most familiar.

Various gases of this character were submitted to the test, from the most rare and expensive to the cheapest and most readily obtainable. As the result of several years' patient and diligent research an entirely new lamp was produced, in which the filament is raised to incandescence by the passage of the electric current in an atmosphere of nitrogen. The globe is first exhausted of atmospheric air, to be charged afterwards with nitrogen. Not only was the light emitted from the glowing filament in this instance found to be the nearest approach to natural sunlight in colour which had yet been accomplished, but, more remarkable still, the consumption of current for a given light equal to so many candles was still further reduced.

The appearance of the nitrogen lamp, as it is colloquially termed, created almost as pronounced a sensation as that of the first Swan carbon filament type. Curiously enough, being possible only in high candle-powers, which are far too excessive for ordinary house lighting, it was hailed as being a powerful rival to the arc-lamp. In fact, it was described as an application of the incandescent filament lamp to the field of arc-lighting, with all the advantages of the two systems and none of the latter's disabilities, such as the renewal of the carbons at frequent intervals. As a result the nitrogen lamp speedily made its way for the illumination of public spaces, streets, and buildings where powerful lights are required. With this lamp the consumption of electricity per candle-power is considerably less than one-half of that of the best type of metallic filament lamp. Up to the present, however, small or low-powered units—from eight to thirty-two candle-power—suitable for ordinary house lighting have not been found possible. But our electrical chemists and scientists are busy in the laboratories, and it is quite possible that the nitrogen lamp will be produced in such a form as to facilitate its utilisation for lighting our homes.

Some years ago another and totally different type of glowing lamp made its appearance. This differs very radically from its consorts both in general design, the tone of the light, and principle of operation. It comprises a long glass tube from which the air is exhausted, and to each end of which a platinum electrode is attached. At one end of this tube is a small bath of mercury which throws off mercury vapour continuously. There is no filament or wire passing through the tube, but the current passes through the vapour, which acts as a conductor, and is induced to glow with a powerful light. The feature of this form of electric illumination is the absence of the red rays in light which prove so inimical to the eyesight. Consequently the light, although powerful and brilliant, is yet soft, of a rich bluish hue, and remarkably restful. It certainly constitutes an ideal illuminant for general and commercial offices, as well as reading-rooms, but cannot be employed in any buildings and trades where colour comparison constitutes part and parcel of the business, the absence of the red rays bringing about strange distortions of colours. Thus objects which appear to be yellow in daylight assume a greenish tinge when viewed in the glow of the mercury lamp. On the other hand, this lamp has the advantage of being economical in the consumption of electric current, this being from one-seventh to one-eighth per candle-power of the obsolete carbon lamp.

Between thirty and fifty years ago inventors were striving might and main to achieve the apparently impossible—the "subdivision of the electric light." Now it would seem as if investigators were endeavouring to resolve the two distinct branches into one again. The new lamp, which has been evolved in the laboratories of the pioneer carbon incandescent filament lamp in Great Britain, may be set down as a distinct combination of the arc and incandescent principles. There is the vacuum glass-bulb of the latter in which is placed two elements, and in which the light is derived by striking an arc between the two. A small ball of tungsten with its connecting wire is placed between a trapeze-like formation of filament, and in such a manner as to come near the cross piece of the trapeze, which is known as the ionising filament. With this lamp two switches are required, one being a push switch similar to that used with electric bells. This is pressed for two or three seconds to energise the ionising filament. Then this is released and the ordinary switch is moved. Instantly an arc is struck between the ball of tungsten and the filament. Although the latter is caused to glow, the greater volume of light proceeds from the tungsten ball, while, in addition, there is the arc between the two contributing its proportion of luminosity. With this lamp an extreme concentration of light is obtained, and this is especially valuable where any focusing of light is desired. This feature renders the lamp of inestimable value in one wide field—as the illuminant in connection with projecting apparatus such as that for animated pictures. Hitherto the arc lamp has been employed exclusively for this purpose, and despite the many objections thereto, the greatest of which is the risk of igniting the celluloid film, it has not been superseded, merely because no other form of electric lighting was found to be equally suitable. This new lamp, described as the "pointolite," solves this problem completely, because it offers the luminosity of the electric arc with the advantages, convenience, and safety of the incandescent filament lamp.

While the electric light is extensively utilised for general and varied illuminating purposes, this by no means exhausts its spheres of usefulness. It is being widely employed for medical purposes, especially in the treatment of certain skin diseases such as tubercular lupus. The best known and most successful of these is that perfected by Dr. Finsen, who contrived a special lamp for the purpose. The light is very powerful, and is particularly rich in the ultra-violet rays, which are of distinct therapeutic value. The Crookes tube, which is employed in connection with X-ray photography, is another type of electric lamp designed to fulfil a specific duty.

The electric light has also been discovered to possess first-class sterilising properties, the ultra-violet rays being fatal to microbic life. The lamps are of special design, so as to secure the maximum intensity of the necessary rays, and the water is passed before the light in a thin sheet or veil. The most deadly germs succumb instantly to the action of these rays, and the most heavily contaminated water can be speedily and cheaply sterilised by this process. Simple installations operating on this system are obtainable for use in the ordinary home, while it may be elaborated to meet the exacting and heavy demands of a densely populated town or city with equal success. Indeed, several plants have been laid down upon the Continent, upon which the citizens depend exclusively upon the germ-destroying properties of the ultra-violet rays in electric light, adapted to the purpose, for their pure drinking water.

CHAPTER XI

The Dawn of Aerial Navigation

THE hour of four was ringing lazily through the haze of the hot, still summer afternoon of August 9th, 1884. Ere the last stroke had vibrated into silence a balloon rose from the French military establishment at Chalais-Meudon. It did not shoot suddenly into the ethereal blue, in the manner of a rocket and which is so characteristic of the ordinary balloon, but ascended slowly and majestically, its upward speed perceptibly diminishing, until at last it came gently to rest.

The eyes of all those within the military aeronautical centre followed the ascent with ill-suppressed excitement, while the unenlightened members of the public, who happened to be in the vicinity, also turned their eyes skyward to rivet them irremovably upon the floating object, their interest becoming additionally keen as a musical droning came down to their ears from above. The floating object exercised a strange fascination; it was quite different from any balloon which had been seen before. It did not follow the usual spherical lines, but with its blunt nose and a tapering tail recalled a huge fish. The idle sightseers around Chalais followed the movement of the vessel towards the capital, while the Parisians thronging the boulevards, as it came within sight, likewise craned their necks to observe the strange form floating above them.

But whereas the gaze of the public was animated purely from motives of curiosity, that of the military at Chalais-Meudon, although every whit as keen, was prompted from a totally different reason. In silence, and scarcely daring to breathe, they followed the course of the slender golden-coloured vessel heading towards the city. There was a strange tension about their attitude which the man in the street could never have fathomed. Presently, one and all gave a sigh of profound relief, followed immediately by frantic rounds of boisterous cheering, which in turn gave way to keen and animated discussion.

There was every excuse for the tense breathlessness and exuberant enthusiasm. That floating vessel represented the answer to years of thought and study and months of practical experiment. Theories which for so long had been merely of academical interest were being subjected to the exacting and critical test of practical application, the outcome of which, if success were achieved, it would be impossible to divine. But the wild huzzas which burst with volcanic force from the throats of the clustered soldiery and officials related only too potently that something momentous had not only been attempted, but had been done. The afternoon of August 9th, 1884, ushered in definitely the era of aerial travel.

The balloon which had been the object of such absorbing attraction was the airship *La France*, and was the creation of Captain Renard, the director of the aeronautical establishment and of his brother officer, Captain Krebs. Six years of patient joint labour were represented in this dirigible measuring 165 feet in length by 27½ feet maximum diameter.

Captains Renard and Krebs had been drawn to the "Conquest of the Air" from the results previously achieved by Henry Giffard in 1855, who sought to propel a gas-inflated vessel through the atmospheric ocean by means of a steam-engine; of Dupuy de Lôme in 1870–72; and of Albert and Gaston Tissandier in 1883.

Dupuy de Lôme attempted to solve this vexatious problem, which had been occupying the minds of men—brilliant and otherwise—for centuries, and the knowledge which he accumulated from his experiments provided the foundation upon which Captains Renard and Krebs pursued their studies. Dupuy de Lôme conceived his idea during the German investiture of the City of Paris. On February 2nd, 1872, a vessel was built according to his designs, and despite the indifferent propelling resources available, he succeeded in imparting a speed of about five miles an hour to his craft in calm air.

In 1883 the brothers Tissandier attacked the issue because by this time an alternative means of propelling an airship had been devised. Gramme had given the world the electric dynamo, and it was thought that thereby aerial navigation might be solved. An electric motor of the type which Siemens had produced but a short while before, and developing 1½ horsepower, was employed, the current being drawn from accumulators. Several experiments therewith were carried out, but the first decisive flight was not made until September, 1884—after the maiden trip of *La France*—when the vessel made a two-hours' sojourn in the air during which it attained a speed of about 13½ feet per second and performed various evolutions.

But it was *La France* and the work of Renard and Krebs which really constituted the starting-point of aerial navigation. These two experimenters set out to build an airship fulfilling the following conditions: stability through the form of the balloon and arrangement of the rudder; diminution of the resistance to its forward movement through selection of dimensions; the approximate determination of the centres of traction and resistance in order to diminish the disturbing momentum of vertical stability; and, above all, the acquisition of a speed capable of resisting the winds that prevail in France throughout three-quarters of the year.

Each of the two experimenters assumed a definite responsibility in connection with the work. Renard devoted his mind to the study of the suspension covering, the determination of the capacity of the balloon—its gaseous content—the arrangements to secure longitudinal stability, the calculations for the dimensions of the details of the car and the invention and construction of a new type of accumulator possessing features of power and lightness. On the other hand, Krebs undertook the many details concerning the construction of the balloon and the means to unite it to the suspension covering, the building of the screw and rudder, the study of the electric motor which resulted in the construction of an engine of unprecedented lightness, up to that time, for a given rating.

The total weight of the airship, including ballast and the two aeronauts, was 4,391 pounds, of which the batteries represented 958 pounds. The electric motor, weighing 215 pounds, developed 8½ horsepower at the propeller-shaft.

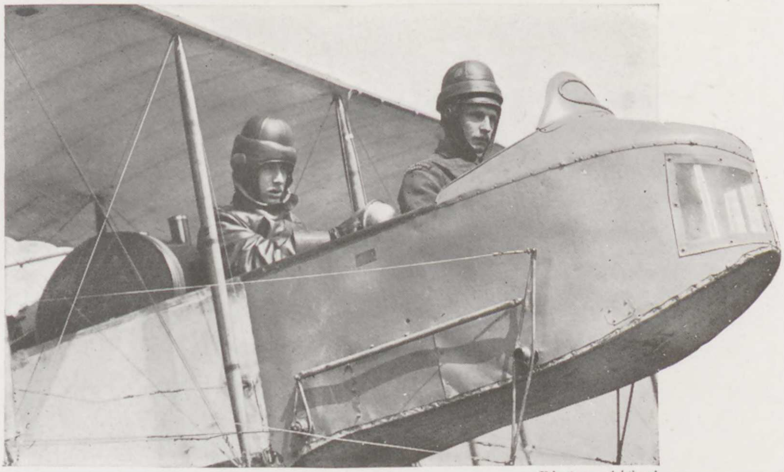


Photo: Alfieri.

A BRITISH MILITARY BIPLANE

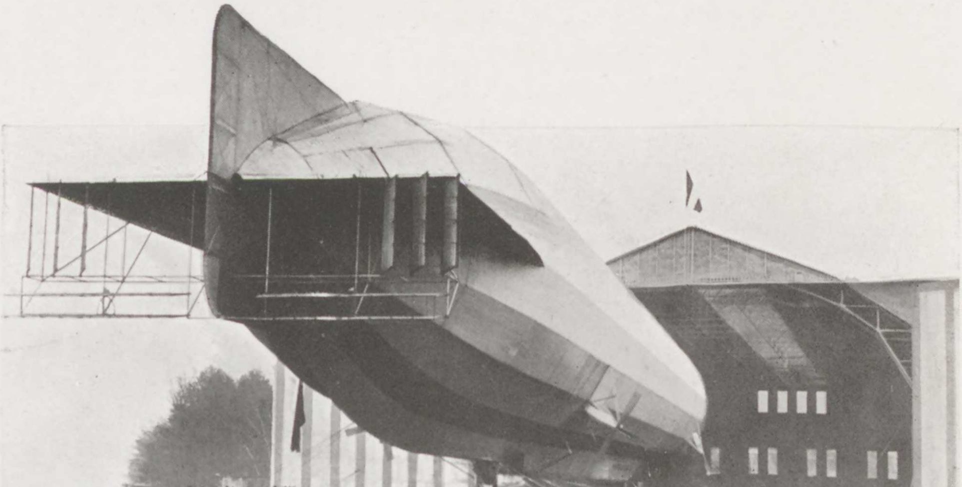


Photo: Record Press.

A GERMAN ZEPPELIN

Upon rising into the air and attaining the desired elevation, the motor was set going, and a course north to south from Châtillon to Verviers was set. At the level of the route running from Choisy to Versailles the airship was swung round towards the latter point so as to avoid collision with the trees. This brought the vessel in due course over Villacoublay, about 2½ miles from Choisy.

Now the aeronauts, Renard and Krebs, perfectly satisfied with the behaviour of their craft, decided to attempt the return to Chalais-Meudon, proposing to descend at the point whence they had started. The rudder was moved over and the vessel, answering her helm, wore round to the right, describing a circle about 492 feet in radius.

The setting of this course brought the aeronautical centre somewhat to the left, but after bearings had been taken the course straight for home was set, to which the airship answered perfectly. A few minutes later she was hovering 980 feet above the field from which she had risen. A point for landing was selected, and to make this the airship was run backwards and forwards several times, until at last, when within 260 feet of the ground, a rope was thrown out. This was caught by soldiers, who speedily drew the ship safely to earth in the field from which she had risen.

It was a wonderful aerial journey, which lasted twenty-three minutes. During this period the airship had travelled a distance of 4½ miles as measured over the ground, and during the run had attained a mean speed of 18 feet per second. The conditions were ideal for such an experiment, the air being virtually quiescent. Nevertheless, the airship had sufficiently demonstrated her virtues as to encourage further investigations. During the journey the aeronauts related that the craft upon several occasions underwent oscillations ranging between two and three degrees, the movement being somewhat similar to the pitching motion of a steamship. This was considered to be attributable to irregularities in form or to local currents of air moving in the vertical plane.

Such was the first successful journey through the air at the will of the aeronaut. It proved conclusively that a vessel could be built which would answer to the desires of the man at the helm, and which could be induced to travel in any direction as required. No longer was the balloon the slave of the air as it had been up to this time. Needless to say, several other aerial trips of this character were made during which the investigators accumulated scientific data of incalculable value, and which have played a prominent part in all subsequent experiments to this end.

Although Renard and Krebs undoubtedly opened the way of the air, little further progress was made for nearly two decades. Not that the subject was neglected; far from it. But because there were difficulties which appeared to be insuperable. The available facilities for driving the vessel were limited and unsuitable. Electric batteries were too weighty and cumbersome, while the loss of gas had to be taken into consideration.

Woelfert attempted to solve the first question by using the Daimler benzine motor, and had his vessel fired and exploded in mid-air by the flames from the engine coming into contact with the gas exuding from the balloon, the result being the death of the inventor and his assistant. Schwartz sought to overcome the loss of the gas by means of an impermeable envelope, using aluminium for this purpose, thus converting his craft into what is known as the rigid type as distinct from the supple or non-rigid form favoured by Renard and Krebs. This effort proved equally disastrous, as the vessel came to earth through failure of the driving system, to be subsequently broken up, partly by the wind and partly through the vandalism of the spectators, who eagerly sought souvenirs of the unique event.

But in 1898 another worker appeared upon the scene—Graf von Zeppelin. By this time the high-speed internal combustion motor, owing to its success in the world of mechanical propulsion over the highways, had become recognised as a suitable engine for aeronautical duty, while a great deal of knowledge concerning the comparatively new metal aluminium had been acquired.

Zeppelin admittedly knew nothing about aeronautics, but he set out to build an airship which differed from all its prototypes in every sense, and particularly in one connection—its colossal dimensions. His first craft measured 420 feet in length by 38 feet in diameter. Two cars were provided—near the bow and towards the stern respectively—in each of which was placed a 16 horse-power motor, driving independent propellers.

But it was the design of this monster craft which aroused the greatest interest, inasmuch as it differed entirely from any which had gone before. The outer shell was polygonal in section, and was built up of a metallic girder skeleton over which was stretched the fabric or skin. Instead of this envelope, as it may be called, being charged with gas in the usual manner—such as a balloon—the interior was subdivided into a number of compartments insulated from one another by a thin wall or diaphragm of fabric. Consequently, the interior of the skin became resolved into a number of cells, and in each of these was placed a balloon inflated with hydrogen. The balloons themselves favoured the conventional spherical form, so that the whole of the cell was not occupied by the gas-bag. This arrangement was adopted because it left a space around the gas-bag through which the air was free to circulate. It was maintained that this arrangement would render the gas-bag less susceptible to the fluctuations of temperature, which cause the hydrogen to expand and to contract respectively, according to heat and cold.

It will be seen from this subdivision, which is still practised, that the interior of a Zeppelin resembles very closely the interior of a ship which is subdivided into watertight compartments by the aid of bulkheads. In the first vessel there were no fewer than seventeen of these compartments, each containing its individual inflated gas-bag. One advantage of this system of construction was pointed out—in the event of one gas-bag being damaged, and its gaseous contents escaping, the descent of the balloon to the ground did not necessarily follow. It would merely cause the vessel to sink to a lower altitude. As a matter of fact, a certain number of the compartments would require to be damaged before the airship was compelled to come to the ground.

Another feature was the means incorporated to tilt the vessel for ascent and descent. The two cars were connected by a long corridor, which space also served to receive a cable along which was moved a sliding weight. When this weight was brought towards the stern of the airship, naturally that end descended to a level below the prow, thereby facilitating the airship climbing to a higher altitude. On the other hand, when it was moved towards the prow, it caused the nose of the airship to sink below the stern, thereby enabling the craft to dive.

The first vessel was not a success, but another was taken in hand, and in this the defects of the original craft were eliminated. This second vessel succeeded, when in mid-air, in travelling at 13 feet per second. This vessel may be said to represent the real starting-point in the evolution of the Zeppelin airship. It is impossible to trace the story of this dirigible through its many failures, disasters, and disappointments, but it may be mentioned that each new vessel represented a distinct advance upon its predecessor. Each successive airship was equipped with more powerful motors, enabling higher speeds to be attained, while similarly the dimensions of each successive airship were increased, giving greater lifting power and increased radius of action—that is, mileage—which it was able to cover upon a single charge of fuel. This evolution has been prosecuted so energetically that to-day we have monster craft nearly twice the height of St. Paul's Cathedral in length, fitted with motors developing 1,000 horsepower, capable of travelling at 58 miles an hour, and able to cover 2,000 miles at reduced speed upon a single charge of fuel, and capable of carrying a load of five tons.

It is unnecessary to dwell upon the achievements of this airship in the grim exigencies of war. As a weapon of destruction we have had ample experience to enable us to judge its capabilities in this direction. The question which is of far greater import is its commercial value. Previous to the war airship services were inaugurated in Germany, and aerial trips and scheduled journeys were carried out with conspicuous success. Count von Zeppelin has expressed his belief that before many months have elapsed he will be able to build a vessel capable of travelling from Europe to America. Already the radius of action has been raised to such a degree as to bring the journey between the north of Ireland and Newfoundland within the range of practicability. The only unknown factor is the weather, and, as events have proved, this is the Zeppelin's worst enemy.

Count von Zeppelin, despite anything which may be said to the contrary, may be regarded as the inventor, pioneer, and only successful exponent of the rigid type of airship. Imitators have striven to eclipse his achievements, but have only met with exasperating failure and disappointment.

But another aerial achievement has served to relegate the rigid dirigible to the background among the nations of the world, with the solitary exception of Germany. This is the aeroplane, or heavier-than-air aerial vessel, which at the moment is absorbing the greatest and widest measure of attention for the simple reason that its future possibilities are quite beyond human calculation.

From the very earliest days man, in his ambition, has sought the conquest of the air by emulating the bird. But the earliest efforts were weird, fantastic, and utterly devoid of any practical value. The majority of the experimenters sought to achieve their end by attaching artificial wings to their bodies, and to copy the bird's movements by the movement of their arms and legs. Needless to say, they accomplished nothing beyond broken bones and bruises, and in some cases a terrible death.

It was a German genius, Otto Lilienthal, who paved the way for the realisation of the flying machine such as we know it to-day. He built a machine comprising wings and a rudder, which might be described as a huge kite, with which he indulged in sailing flights. He approached the problem from the severely scientific point of view, discovering new facts and data for himself. With this contrivance by starting from an artificial hill nearly 100 feet in height he was able to sail over distances up to 1,000 feet. Flushed with the success thus achieved, he endeavoured to propel himself through the air, for which purpose he installed a 2½ horse-power motor, the idea being to move through the air in any direction. Unfortunately, his researches were brought to an abrupt conclusion. While testing a new steering contrivance which he had designed, he fell from a height of 45 feet and broke his spine, from which accident he died on August 10th, 1896.

Contemporaneously with these experiments in Germany, an English marine engineer, Mr. Percy S. Pilcher, was attacking the self-same problem and along almost identical lines. He contrived a gliding apparatus, the knowledge gained from the use of which was quite as, if not more, valuable than that advanced by Lilienthal. Pilcher selected the biplane form of gliding apparatus for his investigations. Flushed with the measure of success which he achieved, he was also tempted to install a motor in his machine.

Indeed, he contrived an aeroplane which may be said to be the father of those in use to-day. He built an oil motor developing 4 horse-power, but although this machine was constructed he never tested it. He resolved to carry out further experiments with his gliding apparatus before trusting himself to a motor-driven machine, and in October, 1899, while giving a demonstration in a park near Rugby, while he was sailing at a height of about 32 feet, a weak part of the machine broke. The accident threw Pilcher to the ground, and he died thirty-four hours later, at the early age of thirty-two years.

As a matter of fact, although considerable merit is paid to the work of Lilienthal, that achieved by Pilcher was far more directly contributory to subsequent investigation, and was far more useful, because he practically outlined the successful flying machine with which we are so familiar at the moment. Lilienthal's contrivance was extremely dangerous. Greater credit is due rather to the man for his courage and perseverance than to his machine.

The dangerous character of the Lilienthal flying apparatus was brought home very convincingly by Mr. A. M. Herring while acting as assistant to Mr. Octave Chanute, of Chicago, Illinois, U.S.A. He built an exact copy of the German investigator's apparatus with which experiments were carried out a month after Lilienthal's untimely end. These trials served to prove how the German worker's fatal accident occurred, and although about one hundred successful glides therewith were made, it was discarded as being far too dangerous and fickle.

Mr. Octave Chanute was deeply interested in the problem of human flight, and expended considerable time and money in a series of beautiful experiments, the information gleaned from which has played an important part in the contemporary flying era. He built several machines with which to test his theories. The first practical appliance had twelve wings, and the outstanding feature, which served to differentiate it from any which had gone before, was the incorporation of facilities whereby the wings might be moved in accordance with the desires of the operator, who stood upright within the machine.

Hitherto the equilibrium of gliding apparatuses had depended upon the movement of the man in relation to the machine. That is to say, the man moved his body. Chanute reversed this practice. He caused the man to be rigid, and the wings to be movable. As events subsequently proved, this was the correct line of experiment.

The multiple-winged machine completed three hundred highly successful flights. Then Chanute decided to reduce the number of wings and built a double-decker, or, as we should term it to-day, a biplane, thereby virtually reverting to Pilcher's apparatus. This machine made some seven hundred flights, or rather glides, and without a single accident. This machine was remarkable for the introduction of a rudder at the rear, which was the idea of Mr. Herring, and this rudder was of such design and operation that the relative wind, catching either its horizontal or vertical planes, altered the angle of incidence of the supporting planes to meet the conditions which arose. Consequently, stability and safety became accentuated.

In view of the success which Chanute had achieved with his double-decker, the question arose as to whether the stage had not been reached at last when a motor might be introduced. Herring believed that an engine might be safely introduced, and in 1897 built a biplane fitted with a benzine engine and propeller. But the motor proving unsatisfactory, it was superseded by a compressed air engine. This propelling system suffered from its severe limitations. A flight exceeding 70 feet in distance was impossible, so Herring devoted his energies to the design and construction of a steam-engine of extremely light weight for the power developed.

Chanute, however, maintained that the introduction of the motor was premature. There were still one or two dubious points of considerable import, which remained to be cleared up. Forthwith he built another machine—a three-decker, or triplane, this time—which was subjected to many searching tests. In this machine the glider gripped the lower front upright members supporting the planes, his legs dangling beneath. When flying and when approaching the ground the man doubled up his legs. This arrangement was adopted for the purpose of facilitating alighting.

Chanute has been described as the father of the heavier-than-air machine, or dynamic flight, and the distinction is well merited. He set out the lines of construction which are still followed fundamentally; introduced the practice of rendering the surfaces movable instead of the man; and strove to secure automatic equilibrium. Certainly his work contributed such valuable results as to prompt other industrious and persevering experimenters to embrace the problem, not only in the United States, but throughout Europe as well.

There were, in particular, two men who, fascinated by Chanute's achievements, took up the subject. They had a small cycle store in the eastern American city of Dayton, Ohio. They were also first-class mechanics, and, in fact, built their own machines. In 1900 these two bicycle makers, Wilbur and Orville Wright, built a gliding machine upon the broad lines favoured by Chanute, but with planes having quite twice the superfices of any which had been tested previously. They also abandoned the upright position for the flier in favour of one prone upon the bottom plane.

Nor was this all. Instead of the tail or rudder at the rear they introduced a similar device in front of the machine, and in such a manner as to be easily and readily controllable by the occupant. But the feature which attracted the greatest measure of attention, and which, indeed, acted as the key to the problem, was a means of warping the wings for maintaining lateral stability while turning. As events proved, this was the vital factor, and represented all the difference between complete and partial success. With this machine more than one hundred glides were made.

It was some time before the work of the Wright brothers attracted any attention. The two experimenters preferred to carry out their investigations far from prying eyes, and to achieve this purpose they went to a lonely, unfrequented sandy stretch of North Carolina. Chanute became interested in their work, and extended them freely the fruits of his experience. In fact, it was Chanute who first communicated some tidings of the work of the Wright brothers, and what they had discovered, to the world at large.

Towards the end of 1901 further details were extended by Mr. Wilbur Wright himself. As they were working only with gliding machines, however, their communication aroused but little interest except in those circles interested in the issue. The years 1900, 1901, and 1902 were devoted solely to gliding, and from which the brothers gathered voluminous data of exceptional value. The machine itself underwent but little modification except in detail, the most important of which was the introduction of a vertical tail to assist in steering and to enable the machine to be held more to her course.

But the two American pioneers merely related what they had accomplished and the discoveries they had made. Not a word was vouchsafed concerning the machine itself, its design, construction, or method of operation. These details were sedulously kept from the public. Accordingly, it is not surprising to learn that their achievements were regarded with considerable scepticism by those investigators who were struggling in the self-same realm in Europe.

The French were particularly energetic. The possibility of human flight was brought vividly home to the general public by the efforts of Santos-Dumont, Captain Ferber, Archdeacon, Blériot, Esnault-Pelterie, the brothers Farman, and Voisin, to mention only a few of the men engaged in the task. The adventures of Santos-Dumont, which were thrilling and exciting in the extreme, attracted the attention of one and all, and the circumstance that he successfully escaped serious injury served to emphasise the fact that travelling, even erratically, through the air was far from being so extremely dangerous as the unenlightened man in the street was disposed to imagine.

Similarly, the aerial acrobatics of Monsieur Louis Blériot, who appeared to be persistently dogged by ill-luck and who was the hero of a hundred and one accidents and smashes, one or two of which were so serious as to leave indelible traces, appealed to the public fancy. They admitted his daring and determination; it appealed irresistibly to the French instinct.

But the enthusiastic appreciation of the general public became riveted upon the conquest of the air from the tempting prizes which commenced to be offered by wealthy patrons of the new sport. The prizes were not offered for impossibilities, but were in the character of enticing steps. Thus Santos-Dumont carried off the prize which had been offered for covering a distance of 100 metres—approximately 100 yards—through the air at Bagatelle on November 12th, 1906. To-day it seems a ridiculously short distance to cover by aeroplane. But it must be remembered that in January of the same year not a single motor-propelled aeroplane had even risen from the ground with a passenger under the power of its motor.

When the first prize had been carried off further awards were offered for 200 metres, which Blériot and Delagrange secured by covering 220 metres through the air. In this way the distance to be flown was gradually increased until it reached a circle of one kilometre—a little more than half a mile—for the successful flight of which £2,000 was offered. Yet this was well and truly won by Henry Farman on January 13th, 1908.

It was the offer of tempting prizes which gave aviation such a far-reaching impetus. It enabled successs to be achieved in far shorter time than would have been the case had the evolution of the new method of locomotion merely been pursued along normal lines. Under the direct encouragement of adequate reward for industry, ingenuity, and perseverance, the length of the highway through the air was increased from 100 metres to a circular kilometre within fourteen months!

Needless to say, the aspirants to fame and the tempting prizes suffered experiences which otherwise would not have come their way. Thus in the early days the experimenters favoured a novel means of determining whether their machines possessed the vital ability of being able to rise into the air. The machines broadly resembled huge kites. They were not fitted with motors right away, but were hitched to fast motor-boats to be towed at high speed. The big kites rested on floats. As the motor-boat settled into its stride, naturally the machine, if of correct design, commenced to rise from the water, and at last attained the maximum height possible owing to the limited length of the towing rope.

Some machines fulfilled their creators' intentions, and rose gracefully from the water to hold themselves in the air while the boat was travelling above a certain speed. Others either declined to slide into the air, while still more, after getting aloft, behaved in the most eccentric manner, dipping and pitching like a small boat at sea in a hurricane.

At times they made a decisive dive towards the water, and in more than one instance further trials were summarily stopped by the machine tumbling into the river with its wings broken. The inventors, proud of their creations, invariably handled their machines, the result being that they were often the victims of impromptu baths; while in one or two instances, owing to becoming entangled in the wreckage, they only escaped drowning by inches.

Gliding became an exciting and popular sport, not only in France, but in America as well. In the latter country some sensational performances were recorded, the new idea appealing especially to those who specialise in feats of daring. Among these was J. M. Maloney, who brought the glider contrived by Professor J. J. Montgomery into public prominence. Maloney was a daring parachutist, and upon the appearance of the Montgomery glider he arranged to demonstrate its capabilities in a thrilling manner. The glider was slung from a hot-air balloon in which the parachutist ascended, and upon reaching the desired height, Maloney, seated in the glider, would cut himself loose and return to earth in a graceful spiral.

The altitudes were gradually increased as Maloney became more and more expert in his handling of the machine until at last he was able to descend from a height of 3,300 feet. When the machine was freed the parachutist demonstrated his complete control over the glider by steering it to the right or left, inducing it to dive sharply, and when a high speed had been attained, would move the elevating rudder to cause the machine to rise slightly. As a rule, the descent from 3,300 feet was accomplished in about thirteen minutes, and the parachutist came to earth within half a mile or so of the point of ascent.

But the trick was attempted once too often. On July 18th the balloon rose amid the plaudits of a big crowd. Reaching an altitude of 2,000 feet, Maloney cut himself adrift. But, unfortunately, in releasing the glider, a rope failed to slip at the critical moment. Evidently it struck and broke one of the struts or guy wires staying the machine. Maloney did not realise the accident. He swooped downwards in an easy spiral until within about 700 feet of the ground, when he set his rudder to make a "deep" or almost vertical dive which never failed to thrill the audience. But the suddenness of the dive threw a sudden and severe strain upon the weakened wing. It broke. Maloney lost control of the glider and came crashing to earth like a falling stone. He died within twenty minutes of being picked up.

The perfection of the petrol motor presented investigators in the world of dynamic flight with the very type of engine for which they had been searching so long and patiently. Here high powers were obtainable for a relatively low weight. Moreover, the motor engineers, embracing the new scientific development, set their minds to building motors especially for aviation service. In this effort marked success was recorded, thanks to the wise employment of light, strong alloys for the working parts, until at last an eight-cylinder engine of 100 horse-power, and yet capable of being carried by an average man without undue exertion, was presented. Other toilers demonstrated their ingenuity in the struggle to secure light weight with high power by the production of the rotary engine. This proved an ideal unit for the monoplane or single-winged machine, which at the time was attracting considerable attention, because therewith high speeds were obtainable.

The year 1908 was one of many sensational achievements in the era of aerial navigation. Experimenters growing bolder and more ambitious, attempted and accomplished cross-country journeys. Henry Farman set the pace on October 30th by flying from Bouy to Rheims, nearly seventeen miles by air, and created further astonishment by putting up a "start to stop" speed of approximately fifty miles an hour. The following day Louis Blériot essayed the round trip between Toury and Artenay, a distance of about nine miles. He not only achieved his object and put up a record of 52½ miles an hour, but he inadvertently revealed the independence of the aeroplane. His magneto broke down, compelling a descent. After a delay of ninety minutes he set off once more and continued in the air until he had to come down a second time. Again he ascended, and came flying to the starting-point as unconcernedly as if returning home from a bicycle ride.

It will be seen that the "Highway of the Air" was being opened for the most part through the persistence of the French experimenters, although some of those who created sensations—such as the brothers Farman—were Britishers. But while France was buzzing with excitement over the exploits of its sons, ominous stories of what the brothers Wright had achieved in America trickled through. They were received with incredulity, because, if they were true, then the achievements recorded in France were dwarfed into insignificance by comparison.

By 1904 the bicycle builders of Dayton concluded that they had carried their experiments to a stage which justified the equipment of a machine with a motor, so as to be able to travel through the air, where, when, and how they wished. Being expert mechanics, they built their own petrol motor. It did not occasion any untoward interest, because it merely followed the most approved type which had proved successful in automobile practice.

The step proved highly promising; 105 flights were made, many being circular, during 1904. The most striking was the negotiation of a field four times in succession.

The report failed to be believed in Europe, because at this time no machine had succeeded in lifting itself into the air under its own power and carrying a passenger. But the end of 1905 brought more startling reports of what the Wright brothers had accomplished. During that year the machine was out only upon a few occasions, the climatic conditions throughout the summer having been unfavourable owing to the heavy rains which converted their experimental field into a lake and quagmire alternately.

But they stated that on September 26th they had made a flight of 11 miles, which was gradually increased until on October 5th they had covered 24¼ miles in the air. Then the experiments suddenly ceased. The American public was becoming too curious for the Wright brothers. Crowds began to assemble around their experimental field. The aviators, apprehensive that details concerning the design and construction of their machine might leak out, drew within their shell to complete the specifications and claims for the patent which they were preparing to file so as to secure the protection which the laws of civilised countries extends to inventors.

But a toiler in this realm is unable to shield his product for ever from public notice. In the case of the Wright brothers their resolution to keep everything to themselves until their claims had received legal protection, owing to the time involved in this essential task, caused the reports of their suggested successes to be keenly disputed. But at last they came out into the open, and in 1908 Orville Wright took his machine to France to give a series of demonstrations. In this manner he fully vindicated the claims which he, together with his brother, had advanced.

At that time, however, the Wright machine was not regarded as a complete success; certainly it was maintained to be inferior to those which had been evolved in Europe. In the first place, it did not ascend under its own effort; an extraneous and elaborate launching device was necessary to send it into the air. This was certainly a disadvantage as compared with the French machines which, owing to the wheeled carriage with which they were fitted, were able to lift themselves into the air.

Moreover, whereas the French machines were able to descend and rise at will so long as there was a certain stretch of comparatively clear and fairly even ground to secure the necessary initial run, the Wright machine could only be sent aloft from set points equipped with the launching device. This was claimed to be an insuperable objection. Returning to the United States, the Wright brothers set to work to remove this disability, and within a few months had brought their machine fully into line with their contemporaries in Europe.

So far as Great Britain was concerned, she lagged far behind. It was not because she had not the brains capable of attacking the problem, but because the efforts of her pioneers failed to meet with appreciation. There was no stimulus here to act as a tonic to native endeavour such as existed in France. It was not until the *Daily Mail*, realising the future of aviation, entered the arena, and by means of the biggest prizes which have ever been offered in connection with the development of a new system of locomotion, roused Britain to excited interest. Tempting awards were offered to the first men who flew across the English Channel, who flew from London to Manchester, and who completed a circuit laid all round the coasts. Curiously enough, however, although the awards were offered principally to encourage native efforts, it was the French designers, builders, and flying men who profited mostly from this generosity. Thus Blériot carried off the cross-Channel prize in 1909; Paulhan, mounted on a Henry Farman biplane, carried off the second prize of £10,000 by flying from London to Manchester in

252 minutes, snatching victory from the British competitor, Grahame-White ; while Védrines completed the French triple event by winning the purse offered for the circuit round Great Britain.

By 1910 the conquest of the air may be said to have been definitely established. It was now merely a question of ascertaining the most profitable field for the new means of locomotion and developing it in accordance with the conditions controlling the approved phase of application. As events have proved, the flying machine—both dirigible and aeroplane—has scored its greatest success as a weapon of destruction ; it cannot be said to have made any valuable contribution to the progress of the world. So far, it has not proved to be of any commercial value, and it is doubtful whether it ever will be of any use in this connection. It is unable to compete with its rivals upon land or sea in the interests of business.

Indeed, at the moment it is impossible to indicate any ramification of industry or endeavour in which it is likely to triumph. The aeroplane has been brought to a standard of perfection beyond which, at the moment, it appears impossible to advance. Possibly some brilliant genius will complete the wonderful revolution which remains to be recorded, and which will have the beneficial effect of enabling locomotion in the air to become reckoned among the blessings of mankind.

CHAPTER XII

Living on the Air

DURING the sixth decade of the eighteenth century a British scientist, whose name to-day is one of the most famous throughout the world of investigation and discovery, was living the life of a recluse in a grand old house upon the outskirts of London. Quietly and undisturbed he pursued his one hobby—science—throughout the livelong day. One line of experiment and research which had been prosecuted industriously and untiringly for many years culminated in a sensational discovery. This was the separation of hydrogen, the lightest gas which is known, and its definite resolution into one of the elements. Henry Cavendish, the scientist toiling in solitude, went farther. He ascertained that the newly-found gas was combustible, and that when burned in the free atmosphere which we breathe, it seized the oxygen, and as a result of the chemical action which ensued was transformed into water.

As we all know, the atmosphere which surrounds this globe and is essential to our existence is composed of two elements—oxygen and nitrogen. Moreover, we realise that the proportion of these two constituents must be one of the former to four of the latter to enable our lungs to perform their functions smoothly and quietly as designed by Nature. Nitrogen, however, is an inert gas, and will not readily combine with any other element.

When Cavendish observed the phenomena occurring from the combustion of hydrogen in free air by means of the electric spark, the question that faced him was: What becomes of the nitrogen? He pursued his investigations to determine this point, and a few years after his discovery of hydrogen he found that at the same time as the combination of the hydrogen and the oxygen formed water, the inert nitrogen became oxidised, and that when this nitric oxide, as it is called, came into contact with the water formed by the combination of the hydrogen and the oxygen, it produced nitric acid.

The experiment carried out by Cavendish excited scientific circles, but, strange to say, it was not followed up, except in a desultory manner. It was regarded purely and simply as an illuminating laboratory demonstration. No one conceived the idea that the discovery might be commercialised and be developed into an important industry.

That was 150 years ago. To-day, what Cavendish produced in his laboratory upon a small scale is being practised upon a huge basis, and, what is more, is being developed with striking rapidity. What has been the reason for this sudden and feverish interest in what was originally considered to be merely a fascinating experiment? The reply is readily forthcoming—to save the world from starvation!

Nitrogen is not only indispensable to the maintenance of our existence. It is equally vital to plant life, though in varying degree. But the vegetable kingdom cannot, so far as we know, absorb the indispensable element through its leaves in a manner comparable with our process of respiration, because the plants are unable to select the nitrogen from the air. This staff of life has to be associated with the soil, so that it may be sucked up by the roots of the plant.

Fortunately for the vegetable kingdom, it is not a difficult matter to administer the nitrogen in this manner, because all fertilisers, both natural and artificial, possess a certain proportion of nitrogen, although the content of this element varies widely, according to the nature of the agent. All decaying matter, both vegetable and animal, contributes a certain proportion of nitrogen, which explains why such refuse is turned into the ground for the stimulation of plant life.

But the needs of the community have grown so rapidly and enormously that what may be described as natural fertilisation has become inadequate. There is one plant more than any other upon which we depend vitally, and consequently it is necessary for us to stimulate this plant to an excessive degree—to force it, as it were, so that its yield shall be twice or thrice of what it would be if left to Nature.

The plant in question is wheat. It has been known since the earliest days as the "staff of life," and never was this colloquialism more true than it is to-day. And yet we are virtually fighting for our existence. The population of the world has multiplied at such a rapid rate as to produce a critical situation, because the yield of wheat is not rising in proportion.

The whole of the white race, and an increasing number of other races which have been and are being brought into contact with the white men, are bread-eaters. In 1908 Sir William Crookes, one of our foremost scientists, stated, as a result of his investigations, that the number of bread-eaters rose by 101,000,000 during the short span of twenty years, and that this enormous rate of increase, far from diminishing with the passage of time, is being maintained, until in 1951 it will have attained the huge total of 893,000,000 people.

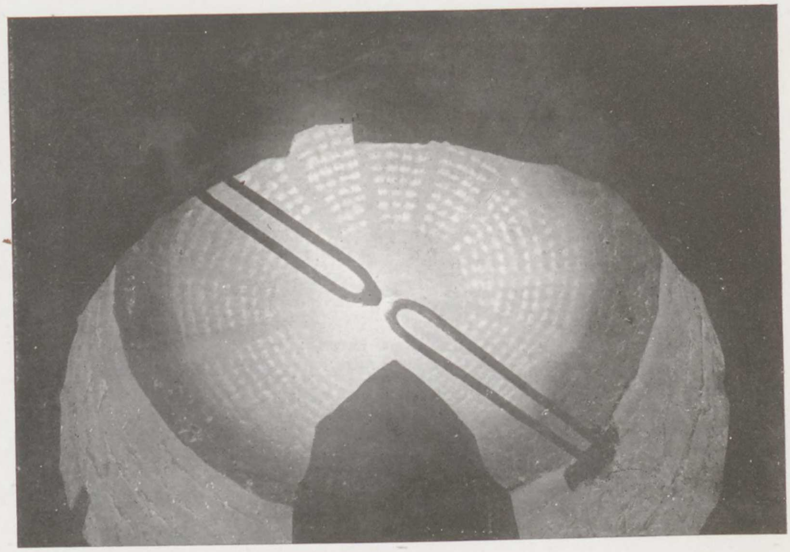
At the moment we may not realise that the growth of the number of bread-eaters is far outstripping the quantity of wheat which is being grown. We look around and observe that new vast stretches of virgin territory, such as the prairies of Canada and the United States, the plateaux of South America and Australia, and the vast steppes of Russia, are being reclaimed and brought under cultivation. We remark that in nearly every instance the cereal which is being raised is wheat, so that we can scarcely credit the fact that the quantity of this grain grown is not keeping pace with the needs of the peoples of the world.

But there is another aspect of the problem which invariably is ignored. As the population increases it wanders farther afield. New cities, towns, villages, and hamlets are springing up with astonishing rapidity in all the new worlds or territories which for years have been regarded as little else than wilderness. A hive of human toilers invariably settles down in a district which has been previously reclaimed for wheat, the result being that large areas of wheatfields are taken over for the construction of buildings, the laying out of streets, and so on. Then the stretches of wheatfields are reduced still further by the inhabitants taking up plots for a variety of purposes

—the cultivation of vegetables, fruit, and a wide selection of other produce. It is a significant fact that when a community rises in a new district which has been reclaimed for the growing of wheat, the cultivation of the latter article immediately commences to diminish in its immediate vicinity. This influence is exerted over a wide radius around the new centre, because it is generally considered that the ground can be rendered more profitable to the owner by raising other commodities.

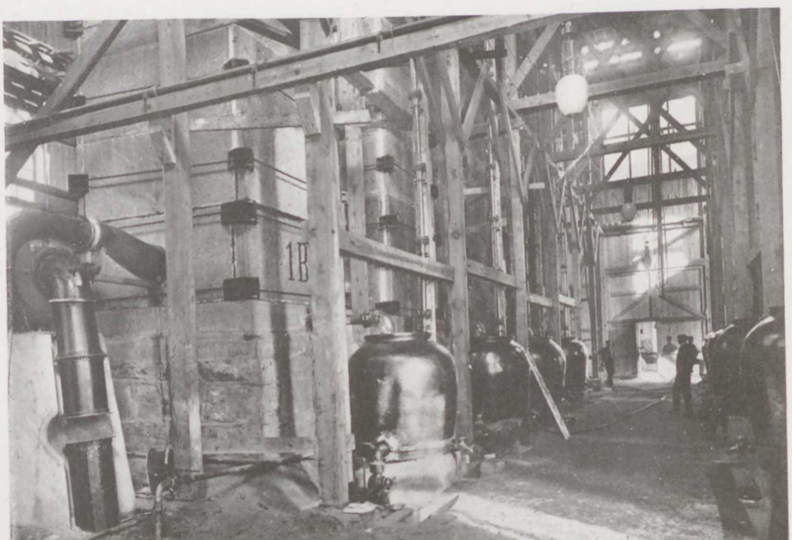
Again, it must also be borne in mind that those who open up new territories, while diligent in working the ground for wheat, are quite satisfied with the bounteous yield given by Nature. The virgin soil is rich, and what the owner considers a fair return per acre is obtained. Thus, in the United States, where the greater part of the wheat is grown upon the prairie, the average yield is about 12 bushels per acre, while in Western Canada it is approximately 15 bushels per acre. This is the yield which Nature gives the farmer. The latter, on his part, makes no effort to assist Nature. He never attempts to replace a fraction of the nitrogenous content of the soil which is extracted and consumed by his crops. The result is that the land in time commences to become impoverished, and the yield per acre falls. Possibly many years may elapse before such a result is observed, but it must occur sooner or later. In some districts, where the soil is termed "poor," it takes place within five or six years; in others, where the soil is rich, half a century may pass before deterioration sets in.

We are so accustomed to the vast wheatfields of



MAKING A FERTILISER

The electric flame in the furnace. During the process the nitrogen contained in the air is burned and converted into nitrous oxide, which is afterwards turned into nitric acid and finally into a fertiliser.



MAKING NITRIC ACID FOR FERTILISERS

The absorption towers wherein the nitrous oxide is absorbed by trickling water to form nitric acid, finally to flow into the huge jars standing at the bases of the towers.

America, Argentina, Australia, and Russia, owing to the enormous aggregate of grain these respective countries produce year by year, that we consider such territories to be literally flowing with milk and honey, where fortunes may be built up within a few years, and to overlook the possibilities in the self-same direction which prevail in the old countries of Europe. Here, owing to the density of the population, and the fact that there is virtually little or no virgin land to be taken over for wheat culture, the aggregate wheat yields per country appear to be insignificant in comparison.

But it is not in the bulk that one must review the problem; it is the yield of wheat per acre which offers the true index to the wheat-raising capacity of the old countries. For instance, in the United Kingdom we raise nearly twice as much per acre as is achieved in Canada, and nearly two and a half times that produced in the United States. The results achieved in Denmark are even more astonishing, the Danish farmers being able to obtain about 50 per cent. more from each acre of ground than is derived in Great Britain.

How is this result achieved? If Denmark can raise some 40 bushels of wheat per acre, why cannot they do the same thing in the new wheat-bearing territories of the world? The answer is that the farmers of the Old World, from sheer force of circumstances, are compelled to exploit their land scientifically, and to rely more and more upon the fruits of laboratory investigation and experiment. The land has been zealously tilled for centuries; the natural nitrogenous wealth which it once possessed was exhausted hundreds of years ago. The farmer is compelled to stimulate his soil, to inject nitrogen in large quantities, as it were, in order to earn sufficient to profit from the sweat of his brow. If he did not embrace the results of science his land would bring him ruin, and that within a very short period.

But science is not content with restoring the soil to its approximate virgin richness. It discovered that, if the latter were stimulated, the yield per acre might be increased two- and threefold. Consequently it enriches the worked soil to an excessive degree with the express purpose of securing the very highest yield per acre which can be attained. The farmer in the new countries will not appreciate the work of science. It represents a certain expense which, in the blindness of his conceit, he refuses to incur, ignoring the fact that by the expenditure of a penny he may get back a shilling or more.

Wheat may be described as the glutton of the vegetable world for nitrogen. But the nitrogen must be served in a special manner—in the form of nitrates, nitrites, or ammonia. While all forms are employed, it is the first-named, as nitrate of soda, which constitutes the staple fertiliser. Upon the lofty flanks of the Andes and among the shore hills of Chile large beds of this nourishing agent exist, and Chile has become the universal provider in this commodity. It is only within the past few years, comparatively speaking, that the value of these deposits of saltpetre, to quote the familiar description of the mineral, has become recognised. In 1830 nothing was known about Chilian nitrate, and even in 1850 the quantity exported to different parts of the world was so small as to be negligible. Suddenly the value of the agent became appreciated. Railways were laid down tapping the deposits, which were worked feverishly. By the early 'seventies the world realised that it could not do without the article, the result being that the annual export of the fertiliser increased by leaps and bounds, rising from 200,000 to 1,400,000 tons in thirty years. And of this huge total 75 per cent., or over 1,000,000 tons, are used for feeding wheat-raising lands for the express purpose of getting absolutely the uttermost bushel per acre.

The value of Chilian saltpetre as a wheat stimulant was convincingly demonstrated by Sir John Lawes and Sir Henry Gilbert, the results of whose studies were communicated to the world by Sir William Crookes. At Rothamstead a field was selected and sown year after year for thirteen years with wheat, no fertiliser whatever being used. These conditions, it may be remarked, are comparable with those existing to-day in the United States, Canada, and other new wheat-growing territories. And, strange to say, the annual yield was comparable with what the American and Canadian farmers obtain, averaging 12 bushels per acre for the thirteen years. The soil was then dressed with Chilian saltpetre and grown with wheat under these conditions for another thirteen consecutive years, the fertiliser being applied every year. The results were astonishing; the yield of wheat per acre jumped from 12 bushels to 36½ bushels. In other words, the stimulation of the soil increased the yield by 300 per cent.! If what was done at Rothamstead were repeated in those new territories, the annual yield of wheat throughout the world, allowing for contingencies, could easily be doubled, and that without bringing a further acre of ground under cultivation.

But, fortunately for the older countries, where the saltpetre is absolutely indispensable, the wheat raisers in the new territories have turned a deaf ear and a blind eye towards achievements of this character. Had they accepted the lesson thus taught, and decided to profit from science, they would have created such a demand for the natural fertiliser as would have been absolutely beyond the limits of those mining the mineral. Moreover, there was another alarming circumstance. Although the saltpetre beds of Chile are gigantic, they are not inexhaustible; and if the maximum demand were suddenly imposed throughout the world they would speedily be worked out, or the price of the fertiliser be forced to such a high figure as to become prohibitive to all but the wealthiest farmers.

Our chemists realised the critical situation which might arise. Forthwith efforts were made to determine whether it were not possible to reproduce a fertiliser comparable with the Chilian nitrate of soda upon a commercial scale and at such a low figure as to be able to compete with the latter. If this end were accomplished, then the exhaustion of the natural nitrate beds would not affect the welfare of the nations, while at the same time a successful synthetic article of equal value would prevent the Chilian article rising to a prohibitive price in consonance with the well-known law of supply and demand.

The problem attracted scientific circles mainly because there was every indication that success might be achieved. The staple element—nitrogen—was immediately to hand. Seeing that it forms four-fifths of the air we breathe, there was not likely to be a dearth of this material, while it was never likely to become expensive to acquire. It is computed that there are some 4,000,000,000,000,000,000 tons of this staple constituent enveloping our earth. What an enormous reservoir upon which to draw for supplies!

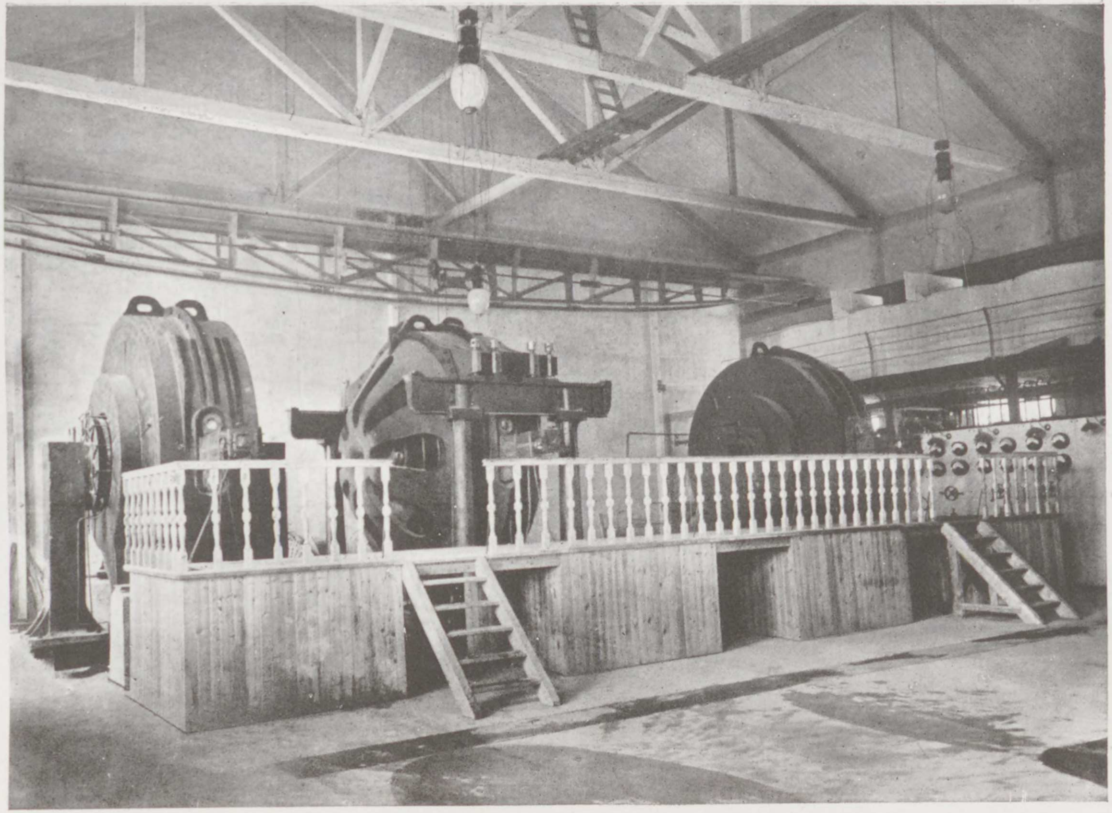
But this nitrogen is "free." That is to say, it is not combined with the oxygen. It requires to be caught, or, as it is termed, "fixed," so that it may be administered to the plant in the form which it is able to assimilate, and through the roots. Fortunately, the means for consummating this end are as readily available as the raw gas itself. It was only necessary to reproduce in a factory what Nature is doing every minute of the day throughout the world where vegetable life exists. Nature fixes the nitrogen in a very simple manner. A flash of lightning, which is but an electric spark upon a gigantic scale, such as Cavendish employed, burns the air, causing the nitrogen to combine with the oxygen. This oxidation process produces nitric oxide. But the fumes, instead of poisoning us, become converted into nitric acid by the falling rain. This acid is brought to earth and, percolating through the soil, enters into combination with the latter, thereby forming the nitrate upon which the plant can feed.

Nature's process sounds extremely simple, as, indeed, it is, but it did not prove such a simple matter to reproduce this action in a controlled manner for the factory. Many an inventor attempted to use the electric spark upon an extensive scale to burn the air, but the majority of results proved impracticable, principally because the electric current proved too expensive to produce.

The great difficulty was not to produce a single spark, or series of sparks, such as Cavendish had employed and in such rapid succession as to resemble a continuous pencil of fire similar to that produced in an ordinary electric arc lamp—a steadily burning electric flame. Sir William Crookes endeavoured to secure the required end, and, in 1892, demonstrated as an experiment before the Royal Society a flame of burning nitrogen. This was nearly 120 years after the momentous discovery made by Cavendish. Sir William Crookes' achievement prompted two French savants to attack the problem. They went a little farther because they were able to produce figures regarding the cost of producing a given quantity of nitric acid per hour. In this way it will be seen that the issue was rapidly being narrowed down to the pounds, shillings and pence aspect, otherwise the commercial possibilities of laboratory researches in this field.

A decided impetus was imparted to the subject by the investigations of Lord Rayleigh in 1897. This famous chemist was engaged in a series of elaborate experiments which culminated in the discovery of argon, but incidentally, by reproducing the experiment of Sir William Crookes upon a larger scale, he was able to contribute more essential details concerning the cost of producing nitrates from the air.

The following year Sir William Crookes returned to the subject. He emphasised the fact that the artificial production of nitrates was no longer merely



FOOD FROM THE AIR

The Electric Furnaces in which an electric arc is "struck" to extract nitrogen from the air.

a laboratory experiment. It could be reduced to practice. The pivot upon which success hinged was the cost of producing the necessary electric current. At that time the Chilian fertiliser was costing £7 10s. per ton, and he pointed out that if the necessary electric energy could be produced so as not to cost more than one-seventeenth of a penny, then nitrates could be made from the air at a cost of £5 per ton, or 33 per cent. cheaper than the natural article could be bought at that time in the open market.

He also emphasised the fact that, while it might not be possible to produce the necessary electric current at such a low price as he set forth in the usual manner—that is, by means of steam, gas, and oil engines—Nature was ready to extend assistance. Water-power would solve the problem, and he drew attention to the vast resources of Niagara in this respect, where millions of horse-power were running to waste and could be inexpensively harnessed.

The eminent chemist's suggestion practically proved the turning-point in the commercial future of the problem. Electricians, chemists, engineers, and scientists in all parts of the world turned their energies towards the solution of the difficulties that now remained to be subjugated. First and foremost an electric furnace, in which the air could be burned, was required. Progress was rapid. In 1902 there came into existence the first commercial company for the production of nitrates from the air. The Atmospheric Products Company was founded in America and acting upon the suggestion of Sir William Crookes, Niagara Falls were pressed into service to supply the electric current cheaply. A special furnace was designed by two industrious inventors, Bradley and Lovejoy, and was set to work. Excellent results were achieved, but the necessary apparatus suffered from the fatal disability of being too complicated for commerce, the upshot being that the first effort to turn Cavendish's discovery to commercial advantage came to an end in the summer of 1904.

But the new industry had advanced to such a stage that it refused to be arrested by this initial failure. While Bradley and Lovejoy were striving to make their system a success, two other investigators had solved the problem. Professor Kristian Birkeland, of Christiania, in collaboration with a fellow-citizen, Mr. Samuel Eyde, a well-known engineer, produced an electric furnace in 1903, the distinctive feature of which was the large intense flame which had been previously laid down by Sir William Crookes as absolutely indispensable to success. For many years Professor Birkeland had devoted his attention to the study of the Aurora Borealis, and these researches had induced him to make several fascinating experiments with electric discharges.

Ten years were devoted to this line of investigation, and as a result of the knowledge he had accumulated so painstakingly, he was induced to probe more closely the peculiar action which a transverse magnetic field exercises upon an alternating electric current passed between the tips of two conductors or electrodes. In the ordinary electric arc lamp, in which alternating current is employed, the luminous flame is but a fraction of an inch in length—the gap between the two points. But the Professor observed that by the aid of magnets bearing upon the arc at right angles the flame could be drawn out so as to form a large roaring disc.

As a result of this discovery Messrs. Birkeland and Eyde decided to build a furnace upon these lines with a view to determining its applicability to the production of atmospheric nitrates. The furnace represents a huge thin drum, built of steel and lined with fireclay. The electrodes are placed within, and it is found possible to obtain a flame about 6 feet in diameter. The air is driven into the burning space in a constant steady stream by means of a blower, and is compelled to traverse the flame so that it must be burned; it is a reproduction of what occurs when a lightning discharge takes place.

The first experimental furnace of 25 horse-power proving satisfactory, a larger furnace of 160 horse-power was constructed with which equally striking success was achieved. Thereupon the inventors established a small commercial plant of 660 horse-power, the results of which were so promising as to encourage them to embark upon a more ambitious programme. A waterfall near Notodden, called the Tinnfoss, where some 2,400 horse-power was running to waste, was secured, and a plant capable of turning out about 5,000 tons of fertilising nitrates per annum when working at full pressure was laid down. But the demand for the product rose so rapidly, as it competed severely with the Chilian article, that the first works proved far too small. Within six months it became necessary to extend the plant sufficiently to enable an output of 50,000 tons per annum to be maintained. For this purpose another waterfall, the Svaelgos, above the Tinnfoss, was harnessed, and in this manner an aggregate of 30,000 horse-power for the generation of electricity was secured.

As is well known, waterfalls are numerous in Norway. The initial triumph at Notodden so favourably impressed the commercial world that other plants were laid down with all speed. It seemed as if every stretch of tumbling water would be taken over to furnish electricity for the production of nitrates from the air. The outstanding feature was the low cost of the current obtained in this way. At Notodden it was about one-fortieth of a penny per unit, which was less than one-half of that set down by Sir William Crookes as being necessary to secure commercial success.

The process is very simple. The air blown into the furnace passes through the electric flame, the temperature of which is estimated to be about 3,000°. The nitric oxide is then driven out of the furnace. The effect of the electric flame upon the atmosphere is strikingly shown because the burned air as it emerges is heavily impregnated with the orange-coloured nitrous fumes. When leaving the furnace the burned air is extremely hot, being between 500° and 750°. The first process is to cool it, after which it passes through a series of granite towers, in each of which streams of water are constantly trickling down. The water absorbs the nitrous fumes, thereby forming nitric acid, the strength of which increases as it passes from one tower to the other. The liquid finally flows into large granite tanks charged with limestone and caustic lime, which become saturated with the acid, thereby producing nitrate of lime. Finally, the nitrated lime is packed for market in suitable receptacles.

While the foregoing process has achieved a great vogue in Norway and other parts of the European continent, another process has been evolved, and has proved equally successful. This is the invention of a German investigator, Professor Franke. This method differs from that perfected by Birkeland and Eyde, in that red-hot calcium carbide, which itself is a product of the electric furnace, is used. As the air is passed over this material the nitrogen becomes absorbed, forming what is known as calcium cyanamide. It is a more direct process, while when the fertiliser is distributed over the land, it undergoes slower decomposition by the moisture to sink into the soil to furnish the roots of the plants with the vital food.

Calcium cyanamide has proved to be comparable with the sulphate of ammonia derived from our gas-works in plant-feeding qualities, and is extensively used in Germany for nourishing the soil. Indeed, in the latter country, enormous works are being laid out for rendering the country independent of Chile, for whose nitrate Germany has been a big customer in past years. Whether such a result will be achieved remains to be seen—the market prices of the respective commodities settles this issue—but there are vast deposits of lignite, generally regarded as an uncommercial fuel, which, it is maintained, can be used for the extensive generation of the necessary electric current at a low figure.

But such a method of seconding the resources of Nature cannot compare with water-power. Moreover, success is not entirely dependent upon the latter consideration. It is equally vital that the limestone shall be in close proximity to the source of energy for producing electricity. In Norway and the United States the two necessaries are found together; hence the profitable exploitation of the processes for extracting nitrates from the atmosphere. In the United Kingdom this industry is unknown—at least for producing fertilisers.

It is certain that the manufacture of these nitrates from atmospheric nitrogen will undergo a tremendous development with the advance of scientific knowledge. The chemists are toiling busily in this field of research. At the present moment the synthetic—or rather atmospheric—saltpetre is not only enabling us to increase our supply of wheat per acre, but is exercising a decided influence upon other industries in which the Chilian nitrate at present holds sway, such as the manufacture of explosives, celluloid, perfumes, dyes, and so on.

That the ability to "fix" atmospheric nitrogen upon a commercial scale has brought us to the threshold of a new world is only too apparent. The achievements of the laboratory can successfully drive away the spectre of starvation among the bread-eating peoples of the world by ensuring our wheat supply.

CHAPTER XIII

The Age of Oil

HALF a century ago the State of Pennsylvania, although within easy reach of the Atlantic seaboard, was almost as unknown and as undeveloped as North-West Canada is to-day. The American steel age had not dawned, and what is now one of the most densely populated and humming reaches of territory forming part and parcel of the United States was virtually given over to agriculture and its kindred callings. Many of the streams which ambled lazily and meanderingly through picturesque dales were unnamed. Indeed, the majority were unknown, and the virgin forest stretched in an unbroken sea of green, brown, and gold from the water's edge to the crests of the rolling hills and knolls.

One day, early in 1859, a small party of men wandered into one of these dales. Evidently they were bent upon a search of considerable moment to themselves, because they tramped the little dale from end to end, probing the ground here, and reconnoitring the never-ending expanse of woodland from somewhere else. Finally, they returned to the floor of the valley, which, owing to the wandering character of the little waterway, was somewhat wide and fairly flat, relieved here and there by ragged tree-clothed clumps.

In due course the little gathering appeared to have come to a decision. In the midst of a knot of trees rising from the floor of the depression a clearing was made. Upon this space a small, quaint, and unkempt wooden structure speedily arose, the felled trees being cut up to provide the necessary constructional material. An unenlightened visitor stumbling across this little party toiling industriously in the virgin forest would have been sorely mystified as to its intentions. Obviously, the men were not contemplating farming, for the simple reason that the building was as unlike any structure generally associated with agricultural operations as it is possible to conceive. Neither were they bent upon raising a rural residence in the wilderness, because the pile was absolutely devoid of any of the features characteristic of a dwelling-house.

The building recalled nothing so much as a crude imitation of a decapitated British oast-house. There was a pyramidal tower rudely fashioned from roughly hewn, sawn, and split trees. From the bottom of this tower projected a shed which appeared to lean upon the pyramid for support. There were no windows; only here and there a rude unglazed opening, while the door was misshapen and crazily built.

But the members of the little community regarded this shanty-like structure with a strange concern and pride. The party numbered only five all told. One, tall, well-built, and bearded, clothed in the frock-coat and chimney-pot hat of the period, was known as "the Colonel." He was the leader of the little expedition, and the building had been indubitably erected at his bidding, for there, boldly blazoned upon a board nailed to one corner of the tower, was his name—"Drake." With him was a tall, attenuated, lantern-jawed young fellow who ever responded to the hail, "Engineer!" The remaining members comprised a family of three, "old Billy Smith" and his two sons, typical Americans of the back-lands or "hay-seed" type. This trio constituted the working staff.

The quintet commenced work on May 20th, 1859, excavating a circular hole in the dim gloom of the building and beneath the apex of the tower. A stranger coming upon the scene might have been pardoned for inquiring the object of their mission. But his inquisitiveness would not have been completely satisfied. He would have received the laconic reply, "Digging for water!" Seeing that the hole resembled the familiar type of water-well he might possibly have accepted the explanation, although he could not have suppressed a feeling of wonder at such vigour being demonstrated in a water-quest, seeing that the crystal stream lazily rolling alongside supplied adequate quantities of this commodity.

But the men were not digging for water, although they encountered it in plenty. They were busily probing Mother Earth for another of her many treasures. A few years previously a British patent had penetrated to the United States and aroused widespread attention. It described the invention of a British chemist, Mr. James Young, who had succeeded in perfecting a simple commercial process for producing a new illuminating medium—paraffin—from crude oil by distillation.

This was a momentous discovery, the value of which was not appreciated so much in Britain as in the big country across the seas. To the American it represented all the difference between comfort and inconvenience, especially if he belonged to the agricultural community, and thus was compelled to live somewhat remote from the towns and cities. Under such conditions life during the winter months was far from being endurable. The long hours of darkness were rather palling. Whereas the town-dwellers were able to benefit from the convenience offered by gas-lighting, the rural dweller was forced to be content with the semi-gloom shed by a flickering tallow candle or rushlight. But Young's discovery offered a means for changing all this. By distilling paraffin from petroleum, which was to be found in plenty throughout the State of Pennsylvania, the farmer living in the country would be brought more on terms of equality with the townsfolk. He would be able to sit at night in a brilliant soft yellow light.

The fact that the United States was rich in this fluid mineral was only too evident from the number of abandoned oil-workings which were to be found, many of which had been exploited in the long and dim distant past. The Indians knew about petroleum, and were in the habit of flocking to these oil-yielding holes for treatment by the medicine men, who had cunningly learned something about the curative properties of petroleum for certain maladies. At Seneca, in New York County, where flowed a petroleum spring, the oil was bottled and sold readily under the title of Seneca Oil.

In some places the oil welled to the surface in the manner of a spring of water. At other spots, where traces were observed, holes or shallow pits were dug, the oil being sought after the manner of gravel and sand in these islands. Upon receiving the notification of Young's discovery an organised attempt to search and dig for oil was made, a company being incorporated in 1854 to this end. But after two years' barren work during which many holes were dug at likely spots, but without encountering a trace of the oil, the project was abandoned, and the company ceased to exist. Three years later Colonel Drake, who had been attracted to the subject, decided to make a further effort, and it was this mission which brought him to the unnamed picturesque sylvan dale in Pennyslvania during the opening weeks of the spring of 1859.

Drake's idea was to sink an oil-well upon the lines of an open water-well, and his engineer concurred in his suggestion. They decided to go down deeply for the new wealth, just as if they were bent upon a large, steady flow of water. All went well for a few days, the hole sinking deeper and deeper with satisfactory speed, owing to the soft nature of the soil in which the excavation was being made. But one day the sinkers, after disappearing a few inches below the level of the ground, had to scamper wildly out of the hole. Water came in with a mad rush; in fact, it welled up so rapidly and wildly as to cause the sides of the hole to cave in, a miniature deep pond being quickly formed.

The party strove desperately to empty the hole, but their most strenuous efforts were unavailing. The water flowed in more rapidly than it could be baled out. Work had to be stopped. But Colonel Drake was not the man to be beaten by an irruption of water. He argued that this nuisance would prevail until the sinkers got down to, and broke through, the solid rock. But the problem was to drive the hole to such a depth. Open well-sinking was impossible unless the three labourers were provided with diving-helmets.

At last, after ruminating upon the problem, Colonel Drake and his engineer decided to see what they could do with the ancient Chinese method of sinking water-wells. It had not only proved highly successful in the land of its origin, where it had been practised from time immemorial, but had been applied with rich results in other parts of the world for tapping subterranean supplies of water. This method is known as the artesian system; by it a pipe is driven into the ground hard on the heels of a drill, which is operated after the manner of a pile-driver and pounds the rebellious earth into dust to be withdrawn by a continuous injection of water, which flushes the debris in the form of mud to the surface.

If water could be secured by the artesian process, why not oil? This was the idea which arose in Drake's mind. To him there seemed no insuperable reason why the method should not succeed, seeing that petroleum was also a liquid. At all events, he would submit the idea to a practical test. Forthwith a stock of piping was purchased and brought to the spot with extreme difficulty and at great expense, the transportation facilities to such an out-of-the-way spot taxing the patience and endeavours of the little party to the utmost. Then the tools for puncturing the ground had to be specially contrived. Under such conditions, despite the enthusiasm and hearty co-operation of Drake and his engineer, supported by the indomitable perseverance of the three labourers, work went forward with exasperating tediousness. Every few minutes would bring the sudden revelation of something unexpected which demanded instant attention. But the difficulties and troubles as they cropped up were attacked and subjugated by the little party, the result being that the length of piping sank deeper and deeper into the ground.

The pipe had notched a depth of 69½ feet on August 27th, 1859, and the drill was being applied with striking zeal. Suddenly there was an excited cry. A dark, greasy substance was welling to the mouth of the pipe. Drake and the engineer craned forward to inspect the substance more closely. As they did so the peculiarly pungent aroma of crude petroleum grew stronger and stronger. Now the water had disappeared, and only the thicker greasy substance was pouring over the top of the pipe. The excitement became intense, and the drill was plied with even greater zest, smashing and pounding at the hard rock. With each successive blow the oil rose with increasing volume. At last the drill broke through the remaining film of rock, and the oil poured out in a bigger and steadier stream.

Oil had been struck! Three months' weary and exasperating work in the woods of Pennsylvania had brought its due reward. As the welling oil increased its flow the party regarded it with a strange amazement. Presently the output appeared to reach its maximum, and they carefully measured the yield. It was 35 gallons an hour!

Colonel Drake had achieved what had hitherto been believed impossible—a belief which had become strengthened from the abortive results attending two years' diligent labour upon the part of a now defunct well-organised company. The news that oil could be won from the earth in the manner of water circulated through the country like wild-fire, creating widespread comment and astonishment.

The inevitable happened. Gold has precipitated wild rushes and booms at intervals throughout the world. But now a new treasure-house of Nature had been unlocked. The oil boom broke out. The excited members of the community, ever ready to experience a new thrill in the race for wealth, rushed to Pennsylvania. The little valley in which Drake had scored such a huge success was overrun by an excited crowd. The land was claimed, parcelled out, and fenced off by prospectors. The forest vanished, the slashing of axe and the whirring of saw resounding throughout the whole twenty-four hours, to clear sites ready to receive reproductions of the strange building which Drake had raised over the first oil-well. The chugging of drills was heard the livelong day and night, and it seemed as if Mother Earth must become honeycombed with pipes for miles around.

The valley, which throughout the centuries had been nameless, was now appropriately christened. Oil had been found within its confines, and it forthwith became known far and wide as Oil Creek. Within a few months the unbroken stretch of picturesque forest was transformed into a sordid, ill-kempt, never-ending stretch of gaunt towers and derricks. While some had bought land in which to seek for oil, others had staked off claims not to work themselves, but to sell out at a profit to others who, arriving late, were yet eager to try their luck. Prices rose rapidly, and a few square feet of land changed hands time after time, always for a higher figure, until tremendous prices were asked and received.

But it was not long before the fever-ridden fortune seekers discovered that Nature distributes her oil in as eccentric a manner as she plants her gold. A well sunk at one place, for instance, was brought into productivity and gave a high yield, to the intense satisfaction of its owner. But a well sunk a few feet to one side steadfastly refused to show anything else but water. The feverishly toiling owner, having sunk the whole of his worldly wealth in buying a claim at a ridiculous figure and installing his plant, became gaunt, haggard, and worried as he saw that fortune resolutely declined to reward his speculation and effort. At last, intensely disgusted with his lot, and bitten hard by grim experience, he abandoned his quest, sold his tools for what they would fetch, and shook the dust of the oil-bearing country from his feet for ever—broken in health, mind, and pocket.

Dame Fortune plays many strange tricks, but probably none is so extraordinary as that associated with what might be termed the coming of the age of oil. In view of the success which he had achieved, and the stupendous revolution which petroleum has wrought upon our complex social and industrial life, one would imagine that Colonel Drake must have amassed a tremendous fortune and have become a millionaire among millionaires. But he did not. As a matter of fact, the evening of his days was harassed by ill-health and sheer want for the bare necessaries of life, while he died in obscurity and almost forgotten. Upon achieving the object which he set out to do he appears to have abandoned all further interest in oil. The quest seems to have appealed to him because it had evidently been set down as impossible. Certain it is that wealth held out no attractions for him. His well continued to yield its 35 gallons an hour for a year, and then flickered out.

The days of '59 in Pennsylvania, following Drake's discovery, compared with those of '49 which attended the revelation of gold in California. The energetic seekers for oil, rationally supposing that if oil existed along Oil Creek if would be found in other parts of the State, pushed farther afield. Sanguine expectations were fulfilled. Oil-wells came into productivity over a wide area. Drake's yield of 35 gallons per hour was considered to be bounteous, but it was completely eclipsed by the strikes which were made shortly afterwards. In fact, so much oil was obtained that the seekers did not know what to do with it. Petroleum threatened to overwhelm and flood the country-side. The railways, river-boats, and wagons were pressed into service to carry it from point to point for subsequent treatment. Ponds were dug to receive it, and enormous tanks, first wrought of wood, and resembling huge vats or tuns, were hurriedly constructed to hold the precious liquid mineral. Subsequently iron and steel superseded wood for the fabrication of the tanks. But the transportation of the crude oil to the refineries offered the most perplexing problem. Even when every available facility had been pressed into service, supply fell short of demand.

THE FIRST OIL WELL SUNK IN PENNSYLVANIA, 1859

Colonel Drake, in tall hat, talking to his engineer. In the background are the three men who sank the well.

At this moment another brilliant genius burst upon the oil world. If water could be pumped from here to there through a pipe, why should not oil be capable of conveyance in a similar manner? True, it might be less fluid than the more plentiful liquid, but that was immaterial. Its sluggish movement could be assisted by mechanical agency. At all events, it was decided to submit the idea to a trial, and a pipe line was laid down. Needless to say, it proved highly successful, and all difficulties concerning the bulk movement of oil seemed to be overcome.

But the genius who conceived the pipe idea was a little too brilliant in the estimation of those among whom he moved. A formidable army of men, the teamsters, who then, as now, ranked as some of the hardest specimens of humanity, were not disposed to submit to such a summary filching of their business. They were making merry and money out of the situation, and were far from being reasonable in their charges for the conveyance of the oil.

Now they were faced with disaster. Those who had invested large sums of money in the purchase of horses, mules, and oxen for the haulage of the tank wagons saw their speculations endangered by the simpler, more expeditious, and cheaper pipe line. So they decided to protect their interests in the only effective manner. They demolished the newfangled idea and cast the fragments to the four winds, at the same time breathing dire threats against those who dared to rob the teamsters of their livelihood.

But the avaricious teamsters were no more able to arrest progress than Canute was able to stop the movement of the tides. The first pipe line was destroyed, but another and more ambitious project was instantly carried into effect, while those interested in this phase of the problem, supported by the oil-well owners, did not hesitate to express their intentions should the line again suffer destruction.

These reciprocatory threats had the desired effect. Surreptitious and guerilla efforts to interfere with the pipe line were made, but the teamsters recognised that they were waging a hopeless conflict, and ultimately withdrew from the scene, completely discomfited, but buoyed up with the hopes of achieving further successes among the new oil-fields which were springing up, and in which they did remarkably well during the brief preliminary period between striking the oil and completing arrangements for its conveyance by pipe line.

But many of those who were favoured by Dame Fortune in the first instance speedily recognised that oil is a fickle treasure. They prided themselves upon their success and the money they were making so easily. But their joy in many instances was short-lived. The successful well exuded its wealth in great volumes for a short while. Then it began to decrease, until it merely trickled, and at last ceased to flow altogether. The well had given out. Drake's well continued to flow for a year before it contributed such little volume of oil as to become unprofitable. But many other wells only enjoyed a fleeting life of a few weeks—in some instances of days only.

As the fickleness of the oil-wells became appreciated it was seen that striking oil was not always the profitable success it appeared at first. In some cases the well gave out before the lucky owner had fully recouped the money he had laid out in this enterprise. There are smiling fields to-day in Pennsylvania which fifty years ago were covered with a bewildering maze of derricks. But the oil gave out, the derricks were dismantled, destroyed, or decayed, and were finally uprooted to enable the once oil-soaked land to be brought under the plough. The maps of the oil region of Pennsylvania printed in the 'sixties offer quaint perusal to-day. The area is dotted with villages, towns, and humming centres born of the oil boom. But you will search the current map in vain for many of those communities. They have literally vanished from the scene, and are now nothing more than memories of strenuous times.

But since Drake struck oil in 1859 the world has witnessed many frenzied oil rushes and booms. And the new oil-fields have been widely scattered, thereby testifying to the liberal manner in which Nature has distributed her reserves of this indispensable commodity. To-day it is India; a year hence it is New Zealand; then Russia, now Alaska, and so on. The booms and rushes swing from pole to pole in the manner of a pendulum. But each sensation merely reproduces the scenes witnessed in the vicinity of Oil Creek in 1859 upon a more or less elaborate scale, according to the character of the discovery.

And Nature rewards the toilers in as strange a manner as she distributes her supplies. Thus, in some parts of Austria, the oil has to be literally torn from the ground; it is too heavy or semi-solid to be pumped. In the Caucasus, Mexico, Borneo, and at many spots in the United States it pours from the earth, once its fetters of rock are broken down, in such frenzy as to spout high into the air like fountains. These are known as "gushers," and the name is excellent in its application. In other regions the oil is more quiescent or sullen, as if reluctant to be drawn from its bed. Then it can only be brought to the surface by means of pumps.

The character of the oil is equally varied. In some places it is almost as fluid as water; in others it is in a jelly-like form. Some is heavily impregnated with asphalt, while other is rich in sulphur. The latter, it may be mentioned, is an unmitigated nuisance.

For many years sulphur oil possessed no commercial value, while it depreciated the value of nearly everything with which it came into contact. But a wizard of chemistry discovered a simple effective means of desulphurising the oil, and its value at once rose to a high figure. Again, one well, while rich in oil, throws out an almost equal quantity of water, which has to be eliminated; then another well is in such a violent state of agitation that the oil gushes forth heavily impregnated with sand, which must also be removed before the oil can be subjected to any subsequent treatment.

Moreover, the precious liquid mineral is discovered in some of the most unexpected places. One would scarcely expect to obtain it in bounteous quantities amid the blistering sands of Persia, but such is the locality from which the British Government derives an appreciable volume of its supplies, the oil being pumped through some 180 miles of pipe line laid upon the sand from the oil-yielding territory to a convenient point for refining and shipment. The low-lying, dismal belt of seashore forming the seaboard of Peru is also dotted freely with the familiar derrick, and oil-winning is actively and profitably prosecuted. Off the Californian seashore the oil beds stretch a considerable distance under the sea. Long narrow piers have been run out, and pipes have been driven through the water to the oil-yielding soil underlying the sea-bed, the nests of towers rising from the water-level presenting a strange spectacle.

But as the exploitation of the dormant oil resources of the earth proceeded apace it was discovered that a plentiful yield is far from being a blessing. As a matter of fact, a prodigious gusher is a curse and a source of constant anxiety until the flow has been brought under control. The greatest enemy of the oil-field is fire, and unfortunately, owing to the haphazard methods and frantic endeavours of the oil-seekers to get rich quickly, precautions are often ignored. The oil, blowing freely hither and thither at the will of the wind, drenches everything. The wooden buildings become saturated with the inflammable liquid, and even the soil itself for miles around becomes converted into a petroleum semi-quagmire. Under such conditions a flash of lightning, a match carelessly thrown down, a lighted cigarette, or even a spark from the drilling machinery is liable to precipitate a holocaust.

The majority of the biggest oil-fields of the world have experienced the full ravages of fire. And an oil-well which falls a victim to the fire-fiend is an untied fiend indeed. The Spindletop Oil-field in Texas was practically blotted out by a fire caused by the gas which was being thrown off coming into contact with a naked light within a confined area. There were 220 derricks on that field at the time, and the greater number vanished in the flames, together with millions of gallons of oil which had been hurriedly collected in tanks and open lakes. On one of the Louisiana oil-fields a frolicsome gusher suddenly caught fire, and the next moment was a roaring, waving fountain of flame. Twenty-five days passed before the fire was extinguished, and it is computed that £200 worth of oil vanished in smoke every hour it was burning.

In the Baku fields fires were formerly of frequent occurrence, and the wells here, being invariably of the gusher type, many remarkable petroleum torches resulted. But the biggest and most notorious oil-fire of all was the " Dos Bocas " well, which, strange to say, ushered in the country of Mexico as a rich oil-producing country, owing to the unprecedented character of the conflagration.

The oil rushed out of the earth with tremendous velocity, shooting high into the air. In fact, the flow broke loose and completely defied all efforts to bring it under control. Nine days after coming to life it was in full activity in more senses than one. The unexpected flow speedily exceeded all the arrangements which had been completed for the reception of the oil. It ran everywhere, and some of the running liquid came into contact with some smouldering ashes. Instantly a terrifying sheet of flame leaped from 1,000 to 1,500 feet into the air, and as the fountain spread out in the form of a fan near its crest, the terrifying spectacle of a flaming sheet 90 feet in width was presented. At night the glare from the burning oil-well was plainly visible from 200 miles out to sea.

As a rule, a burning oil-well can generally be extinguished. But "Dos Bocas" proved absolutely untamable. How much oil vanished in smoke and flame will never be known, but it is computed that 4,000,000 gallons of oil disappeared in this manner during the twenty-four hours. As the fire progressed the well gradually resolved itself into a volcano, the crater of which increased until at last it was 1,000 feet across.

The authorities strove to kill the fire by smothering the flames, and by mining with dynamite so as to cause a tremendous cave-in; but both expedients had to be abandoned. The heat was so intense that approach within 300 feet of the roaring torch was impossible. The Mexican Government assisted the company with 450 sappers, but even this force failed to make any impression.

At last, seeing that "Dos Bocas" was beyond recovery, it was decided to kill the fire by drastic means. Powerful pumps were installed beside a river 2,000 feet away, and they were set going for all they were worth, throwing water into the huge crater that had been formed. Even this heroic measure did not achieve the desired end. After flaring madly for fifty-eight days the fire suddenly collapsed. The well gave out, but only to belch 70,000,000 gallons of salt water a day. Even now the erstwhile gusher is disposed to reassert itself at intervals, but only to hurl salt water and gas into the air for a brief period.

Nowadays, petroleum is fully recognised as being a dangerous master although a servile servant, so no precaution is considered to be superfluous so long as it secures the greater safety of the product.

It is caged in tanks as it comes from the well, and is hurried to the refineries as soon as possible through pipe lines, to be split into the different products which are now so indispensable to commerce.

The refining process itself is prolonged and complicated, involving the utilisation of extensive and elaborate plant. In addition to the mechanical forces, an impressive army of chemists, engineers, and other experts in this or that ramification of commerce have to be retained.

What do we get from petroleum ? If this question were put to the average person he would retort, even after prolonged cogitation, " Oh, about half a dozen articles." But he would be exceedingly wide of the mark. As a matter of fact, industry and commerce depend upon more than two hundred different products which are derived from petroleum—thanks to the chemist, who has proved so unremitting and ingenious in his wizardry.

To-day, nothing of the crude oil is lost but the smell. Even the gas, which is so volatile as to be virtually beyond harnessing, is not permitted to escape idly into the air. It is led into the furnaces to assist in heating the stills.

The lighter oil, known generically as petrol, is first taken off. This is the spirit which serves as the bloodstream to our motors, enabling us to move swiftly upon the earth and waters, above the earth, and formerly —even to-day, in some instances—under the waters.

Then there is paraffin, which serves as an illuminant and a fuel for heavier explosion engines. It also forms an excellent substitute for oils generally derived from the animal and vegetable kingdoms. In this instance a wide vogue prevails owing to the lower price of the substitutes as compared with the genuine articles, although they do not possess the imperative characteristics of the latter.

After that come the heavier oils, which are used for lubricating purposes and are of varying grades and density. These also enter into the pharmacopœia, although this factor becomes more pronounced with the heavier products, such as the paraffin wax from which ointments, salves, drugs, and chewing gum are made. The wax gives us the candle which ousted the tallow dip from its eminence as a light ; plays a prominent part in the manufacture of perfumes, the preparation of crystallised fruits, certain confections, and the making of matches. By blending the petroleum oil products with animal and vegetable oils a wide range of " compound oils," which are used for a hundred and one different purposes, are obtained.

Lastly, there are the solid products, which are generically described as " residue." But, as a matter of fact, it is not a residue in the sense of a waste product. If the crude oil belongs to what is termed the paraffin group, then this residue takes the form of a coke, not widely dissimilar from that produced by the distillation of coal in the production of gas. This coke is an excellent fuel, but is not used in this direction, because a more valuable use for it was discovered. From this is made the carbons upon which electric arc-lighting depends. If the crude oil belongs to what is called the asphaltic group, then the residue is an asphalt which is now being extensively used in road construction. The asphalt in turn yields bitumen, which is in demand for the manufacture of cables for the transmission of electricity, telegraphic, and telephonic purposes.

Nor have the possible uses for petroleum products yet been exhausted. The chemists are toiling zealously and patiently in the laboratory, and are constantly indicating other and equally profitable fields of application. To-day, the science of applied chemistry in connection with petroleum has been advanced to such a stage as to induce one to wonder whether, in the near future, petroleum will not constitute an indispensable fundamental element in the preparation of artificial foodstuffs.

But the enormous reliance which the world has come to place in oil is exercising one inevitable effect. It is becoming more and more difficult and expensive to win it from the earth. We have seen how Colonel Drake struck oil at a depth of 69½ feet, and the cost of sinking his well could not have exceeded two or three hundred pounds, the expense in this instance having been inflated by the fact that he had to conduct pioneering operations which necessarily involve excessive outlay. Even to-day it is possible to sink a well and to tap oil for a disbursement of a few pounds, but the yield will not be adequate to transform one into a millionaire, unless fickle Fortune is extraordinarily kind. Neither is the life of such a well likely to be very prolonged.

The upper layers of oil, especially in the proved and worked fields, are being rapidly depleted, thereby compelling the sinker to drive his pipe deeper and deeper into the earth's crust. This causes the price of drilling to rise very materially. In the United States wells are now being sunk to the 1,000-foot level. In Mexico they generally have to be carried to the 1,500-foot mark. In Burma, another rich oil-yielding country, and Roumania, they are being continued to far greater depths, the uppermost beds having been exhausted to such a degree as to be unprofitable. By driving deeper it is possible to tap another bed of equal if not greater wealth. In Galicia the majority of drills have to be carried down to 3,000 and 4,000 feet, while some have passed the "mile deep" limit. Under these circumstances the cost of sinking an oil-well may very easily involve an outlay ranging between £3,000 and £6,000 or more.

The early well-drillers were not slow to observe one curious circumstance attending their task. As the oil bed was approached powerful indications of the fact became observable. Large volumes of oil-gas welled up the borehole. In those days the drillers regarded this vapour as an unmitigated nuisance. Its presence behoved them to take more than ordinary precautions that there were no naked lights—not even a cigarette—within the vicinity. If there were, then the gas spreading along the surface of the ground was likely to quarrel with the light, the result being a terrifying and exasperating conflagration. As a rule, when this gas was detected, arrangements were completed for drawing it off, carrying it through piping to a distant point, and there allowing it to be consumed in the open air by merely applying a light to the open pipe-end.

But as the oil industry developed, and the haphazard gave way to more scientific methods, ingenious minds began to inquire whether this gas could not be turned to useful account. It was examined and found to be comparable with that derived from the distillation of coal. The more enterprising oil-seekers thereupon trapped this gas and led it to the furnaces of their pumping plants, thereby inducing the well to furnish its own power to enable the oil to be tapped.

But such huge volumes of gas were obtained that it could not all be consumed even in this manner. Thereupon it was decided to distribute the article, which was suitable for power, heat, and light, through mains, in the manner of coal-gas, and to supply it to one and all who felt so disposed to take avail of this convenience. For a time this enterprise languished: the value of the gas from the general point of view failed to meet with appreciation. The ingenious development was saved, however, by manufacturers stepping in and purchasing the new fuel. It was cheaper than coal, and more convenient to handle.

Once the value of the article had become realised and public confidence in the regularity of the supply was gained, the consumption of natural gas, as it is called, went ahead by leaps and bounds. To-day, in the United States, it constitutes a serious rival to coal-gas, and in many instances is pumped from 100 to 150 or more miles from an oil-field, where it is not required, to some humming centre where it is in urgent demand. The city of Chicago, which is a large consumer of natural gas, draws its supplies from a point over 120 miles away. As a matter of fact, natural gas ranks as sixth in importance among the natural resources of the United States, which serves to convey an adequate idea of its value and popularity.

In Canada, too, it is rising in favour. This applies especially to Alberta, which province appears to be lying upon a huge natural gasometer. Medicine Hat is the centre of this industry, and the residents of that favoured city must certainly be accounted "lucky" when compared with the town-dwellers of these islands. There the housewife is able to buy gas for lighting and cooking at a cost of 7d. per 1,000 cubic feet! In the majority of towns in Great Britain the commodity costs about four times as much. The small manufacturer is even better off, because he pays only one-half these rates, while if one is prepared to introduce an industry upon a large scale, one can make a long-term contract for an adequate supply at ½d. per 1,000 cubic feet!

The gas is drawn from a depth of about 1,000 feet, and is tapped after the manner favoured in oil-well sinking. The enterprise is carried on by the city authorities, who have been granted rights to exploit and to supply the article throughout an area of 144 square miles. The gas rises to the surface at a pressure of about 500 pounds per square inch, but by means of regulating valves is fed to the domestic consumer at a pressure of 6 ounces per square inch. Curiously enough, the gas is not conveyed first to gasometers, but is supplied to the tap direct from the bowels of the earth—surely the acme of simplicity in gas supply!

One of the most remarkable features of the oil industry—one which is as striking as refining itself and the subdivision of the crude oil into products influencing some 200 applications—is the revolution which has been wrought in the transport of the oil. Where the conditions are amenable, cross-country movement is effected by means of pipe-lines as already explained. Some idea of the huge strides effected in this branch of the problem may be gathered from the fact that the day is not far distant when it will be possible to pump oil right across the United States from seaboard to seaboard, a distance of approximately 3,500 miles. Even this method of movement is inadequate to the demand, and, as in this country, a considerable volume is moved by railway in large tank wagons and by barges.

In the early days of ocean transportation the oil was packed in barrels. But this method proved wasteful owing to the amount of space which could not be occupied, such as the interstices between the circular barrels. Accordingly, it was decided to test the possibility of carrying the oil in bulk. In this instance the whole of the available freight-carrying capacity of a vessel is built in the form of large wells or tanks into which the oil is pumped through hoses, its removal being carried out in a similar manner.

Not only was it found possible to carry oil in this manner and in larger paying quantities per trip, but loading and unloading were reduced to a simple, inexpensive, and rapid task. The tank steamer became recognised as the ideal vessel for carrying oil across the seas in bulk. This movement has developed to such a degree that to-day we have tankers capable of carrying 8,000 tons or more of oil as a single cargo. In addition, a barge, of similar construction and of proportionate capacity, is attached to the steamer and towed across the ocean, so that the movement of oil per trip is increased very appreciably.

If we look around we can see evidences on all sides of the wonderful revolution which oil has wrought upon our very existence. It has brought in the motor-car for pleasure and commerce, and the motor-bus and taxi-cabs which rank to-day as the fleetest and most mobile vehicles engaged in the public service. It has contributed to the conquest of the air, and is even revolutionising movement across the seven seas.

It is threatening coal as fuel for our steamships. Whereas stoking with the solid fuel imposes a pronounced strain upon physical effort, there is nothing so simple as oil-firing. Exertion is confined to the turning of a tap, while the stokehold is cleaner and more endurable to humanity.

From the point of national security oil has rendered us invaluable assistance, inasmuch as it has directly provided us with the fastest and most formidable capital warship afloat. Indeed, all things considered, it may be said in very truth that the community is becoming daily more and more dependent upon petroleum; it promises to survive as the one force which will drive the world.

CHAPTER XIV

The Rise of the Motor-Propelled Vehicle

In a small workshop a solitary man was working quietly in secret throughout the hours of daylight and often far into the night, under the feeble flicker shed by a rushlight. His neighbours often remarked among themselves upon the long hours the man toiled, and discussed, with ill-suppressed curiosity, the nature of the task which demanded so much zeal, patience, and prolonged stretches of labour. But 1769 was a year when modern machine tools were unknown; when there was no steel; a period when one had to work patiently and diligently by hand in the few metals which, up to that time, had entered the realm of commerce.

At last the task was completed. The doors leading to the yard were opened, and through them came a vehicle such as had never been seen before. At the first glimpse the unenlightened good French citizens dwelling in the locality fled in terror. It came chugging into the street. When the first wave of fear had passed, excited curiosity took possession of one and all, and they crowded around the weird-looking monster now standing at rest, surveying the quaint, huge copper kettle which hung over the front wheel of the carriage.

Again it commenced to chug, and carrying its creator and three friends, it moved along the road at a speed of about two miles an hour for some fifteen minutes. Then it again came to a stop, to resume its journey after another long drink.

The citizens marvelled. To them it appeared to be uncanny, if not actually flying in the face of Providence, to travel along the street in a carriage to which no horse was attached. But they remarked that the animal—they confidently believed that some creature was imprisoned within—evidently was afflicted with a prodigious thirst, because observe how frequently the carriage had to be stopped, and what a quantity of water was swallowed!

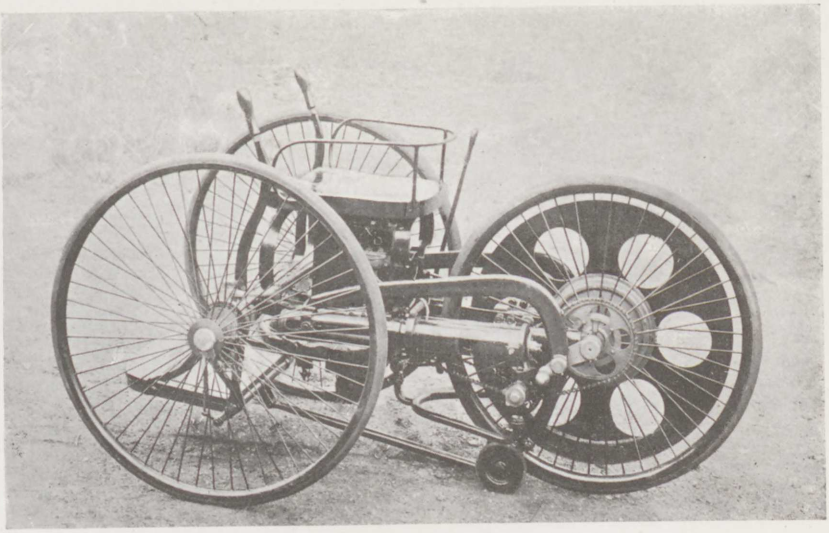
Such was the first steam-propelled carriage, which, designed and built by the ingenious French military engineer, Nicholas Joseph Cugnot, proved its ability to move along the highways without the assistance of animal or manual effort. After several short runs along the road adjacent to the workshop, which had been regarded with so much curiosity for so many months, the inventor essayed to give a public demonstration. But he had not completely mastered the eccentricities of his strange steed. The master mind at the wheel attempted to make a turn while running at full speed. Unhappily his car was top-heavy. It canted and shot into a building which proved immovable, and the car was reduced to a hopeless, overturned wreck.

But Cugnot had accomplished sufficient to attract the attention of his superiors—the Military Department. Two years later the Government commissioned him to build another steam tractor, for the haulage of artillery. They stipulated that it should be able to carry a load of 4½ tons and have a speed of 2¼ miles an hour. As evidence of their faith in the inventor's work, they advanced him £800 with which to build the vehicle. It was duly completed, but unfortunately never was used. The French Revolution supervened and destroyed all the inventor's hopes. His efforts, however, did not go unrewarded. Napoleon extended his appreciation of the military engineer's ingenuity and industry by the award of a pension.

Cugnot's carriage to-day would be described as a steam tricycle, a three-wheeled fore-carriage or a tractor. The chassis comprised a timber frame, while the boiler, fashioned from copper and of peculiar shape, was placed over and slightly in advance of the front wheel, which acted as the driver. The steam passed from the boiler to operate two single-acting inverted cylinders having a stroke and bore of 13 inches, the transmission to the front wheel, which was also the steering wheel, being through pawl-and-ratchet gearing.

Cugnot's second carriage, although never used, did not pass to the scrap-heap during the great national upheaval. It was subsequently brought to light, and is now preserved as an historic relic of great interest in the Conservatoire des Ārts et Métiers in Paris. Cugnot's carriage may be said to have opened and closed the first stage in the self-propelled carriage era, because nothing farther in this field appears to have been done for another sixteen years.

Then a British engineer, William Murdock, revived the interest in the problem by building a small three-wheeled model fitted with a steam-engine. He is stated to have demonstrated it to his intimate friends in his drawing-room, where he illustrated its carrying capacities by loading it with the fire-irons and sending it upon wild trips in an obstacle race among the



BUTLER'S TRI-CAR

This, the predecessor of the modern motor-car, was the first self-propelled vehicle of British design.

THE FIRST BRITISH-BUILT MOTOR-CAR

Built by John Henry Knight, Esq.

furniture. Subsequently he submitted it to a high-road test, late at night, upon the roads of his native town of Redruth, only to throw the good vicar, who was taking the air in the darkness, into abject fear. Seeing the engine coming along the road belching sparks, smoke, and flame, and terrified by the chug-chugging of the monster, the worthy man turned and fled in mad haste, firmly believing, as Smiles relates, that the Evil One was after him *in propriâ personâ.*

There is no doubt but that Murdock, flushed by his success on the high road, would have attempted further experiments upon a larger scale had it not been for the dissuasion of Watt, who feared that the new channel of thought would interfere with Murdock's work at the Cornish mines. At all events, Murdock seems to have abandoned the idea which he was contemplating, and his name does not appear to be linked with further development.

But seventeen years later a contemporary engineer, Richard Trevithick, brought out his proposal for a road engine. In general appearance it was not dissimilar from the steam-railway locomotive which appeared a little later. The engine, however, possessed one notable feature, and this was a system of gear transmission to the driving wheels. Trevithick, like Murdock, was prompted to test his creation upon the high roads, but the authorities were soon hot upon his track. One day, while joy-riding at the terrifying (?) speed of 10 miles an hour, his engine ran somewhat amok and crashed into a fence! It was the latter and not the engine which suffered, several palings being stripped off. For this heinous offence Trevithick was sternly warned off the highways with his diabolical invention, which was construed into a menace to the peace, quietness, and safety of the community.

The efforts of Cugnot, Murdock, and Trevithick had not failed to arouse the attention of energetic and enterprising brilliant minds, who saw that the time must inevitably come when, contrary to the prevailing belief, "carriages without horses shall go," and along the public roads. The coming of the railway locomotive had proved this very conclusively, and although the success of George Stephenson served to attract the greatest meed of popular attention to the iron way, the possibilities of similar traffic over the public thoroughfares was not overlooked.

In 1826 Sir Goldsworthy Gurney introduced a steam-driven coach, weighing 3½ tons, the steam being raised by a water-tube boiler, and is said to have attained a speed of 20 miles an hour. In 1831 this pioneer decided to compete directly for public traffic by inaugurating a regular service between Gloucester and Cheltenham. This ranks as the first ambitious and commercial effort to popularise the self-propelled road vehicle.

Gurney's apparent success spurred a contemporary pioneer, Walter Hancock, to endeavour to revolutionise vehicular traffic in the metropolitan area. Services were arranged between various points, such as between Stratford, Paddington, and Moorgate. But a public which had been accustomed for centuries to "Shanks's Pony," crawling horse-drawn vehicles and sedan chairs, did not regard the innovation with any favour. They resented the attempt to hustle them and to speed-up the whole spirit of trade and movement. They condemned the horseless carriages as a decided danger to the welfare of the community, and voiced loud and long their complaints concerning the smoke, steam, and hot ashes which contaminated the streets, rendering the air absolutely unbreathable by pedestrians and others frequenting the thoroughfares.

The new steam-driven carriages were regarded as eminently dangerous, which perhaps was not surprising, seeing that previously no efforts had been made to move at more than 4 miles an hour along the public highways. This antipathy was not alleviated by one or two accidents which attended the steam-cars. The risk of being blown to pieces by the explosive steam was supported by an accident to the Paddington coach, which brought about the premature death of its driver.

The inquest was followed with the greatest interest, and the antagonistic element refused to be convinced, despite the official inquiry revealing the circumstance that the driver, in the wisdom of his conceit, cherished peculiar and not generally accepted opinions concerning the handling and properties of steam. The objections which were smouldering were fanned into flame by another accident in Aldgate. A horse-drawn vehicle essayed to dispute the right-of-way with a steam-bus, with dire results. The perverse driver, after being worsted in an encounter in which he was undeniably the challenger, revealed his true inward feelings and opinion concerning steam traction in no uncertain manner.

However, despite these handicaps, it is quite possible that Hancock, who was striving might and main to educate the public to an order of things which was certain to come, would have prevailed. But to his discomfiture he learned that there is always something more powerful than mere public antagonism to anything new. He was trenching seriously upon the preserves of vested interests. Stage-coach proprietors, who were already beginning to feel the effects of the competition offered by the steam railways, but whose wails fell upon deaf ears, now turned to assault the new arrival upon the roads with additional vehemence and acerbity.

They assumed an attitude which was apparently animated from motives of kindness to animals. They urged that steam and animals could not run side by side; the animals were certain to suffer. This craftily conceived objection had the effect which was desired. It ranged all animal lovers, who were then in an overwhelming preponderance, upon their side. Then there was the damage which was being inflicted upon the road surfaces, and which was declared to be due to the faster moving and heavier steam cars. Who was to pay for the necessary repairs?

Such a cunningly contrived campaign of hostility was certain to bear fruit. If the steam rival could not be summarily ejected from the highways by legal procedure, then an alternative method must be adopted. The vehicles must be harassed and subjected to intolerable pettifogging taxation so that all possibilities of rendering the enterprises profitable might be effectively prevented. In this vested interests were successful. Whereas the tolls for horsed vehicles were only 3s., steam cars were mulcted to the tune of £2! Needless to say, it would have required the resources of a millionaire to have maintained a public service in the face of these conditions. Hancock did not happen to be a millionaire and so he bowed to the inexorable decree of Fate. He withdrew his vehicles, literally hounded off the streets.

But it must not be imagined for a single moment that all these pioneers calmly submitted to the public wrath. Then, as now, cunning resort was made to subterfuge in the hope of achieving the desired end without coming into conflict with the powers that appeared to hold the whip hand. As the greater objection arose from the pollution of the streets during the day, when they were thronged with other traffic, both pedestrian and vehicular, one or two of the advocates of the new system of locomotion decided to run their vehicles during the night, when the highways were deserted and all good people and animals were at rest.

This move proved highly successful for a time and during 1861 the nocturnal steam-driven coaches plied a thriving trade. Owing to operations being conducted during the hours of darkness, a vehicle engaged in this business became christened as the "fly-by-night." The enthusiastic owner of such a carriage rather enjoyed the nocturnal ride. The roadways being free of other traffic, there was the chance "to open her out and to let her go for all she was worth." The ability to thunder along the roads and to rattle and chug through villages at 10 to 15 miles an hour provided a new and thrilling sensation.

But the guardians of the community came to the alert. The residents along the highway frequented by such a fearsome monster declaimed loudly against their sleep being rudely disturbed by the fearful din which the carriage created, which sounded additionally fearsome amid the silence of the night. As a result, the police swooped down, and things once again became uncomfortable for the pioneer. Now he was harassed by being stopped at such frequent intervals as to render travel virtually impossible.

But he was not dismayed. He decided to give some apparently tangible excuse for tearing along the roads at all hours of the night. Forthwith the driver and other men mounted upon the vehicle were dressed up with helmets and coats to resemble firemen, while, to complete the illusion, buckets and other fire-fighting impedimenta of the period were carried and boldly displayed. In this manner the owner of the vehicle succeeded in hoodwinking the police, who, when they saw the vehicle come roaring towards them, naturally thought that it was hurrying with all speed upon an errand of mercy instead of one of sordid commercial import. But this manifestation of brilliant ingenuity did not enjoy a long vogue; the police saw through the ruse, realised how completely they had been gulled, and forthwith asserted their power with all the stringency they could command.

In 1865 all further fertile and energetic effort upon the part of British workers was completely scotched by the passing of one of the most grandmotherly and setting-back-the-clock Acts which has ever been entered upon the Statute Book of Great Britain. That year saw the promulgation of the Locomotive Acts, which later became cynically known as the "Red Flag Act." Self-propelled vehicles were not forbidden upon the public highways. Oh, no! But they were not to travel at a speed exceeding four miles an hour, and, moreover, must be preceded by a man carrying a red flag to warn others using the highway of the approach of the Juggernaut!

As might be readily imagined, such an obtuse and repressive Act of the legislature effectively prevented any further developments in this field so far as Great Britain were concerned. It was sheer waste of time for an inventor, no matter how brilliant he might be, to trouble his brain two seconds about a self-propelling idea for carriages. It could not be exploited profitably owing to the ridiculous legal restrictions. And as there was no object in striving to perfect a horseless carriage which would be prevented from exceeding a walking horse in pace, financiers were not likely to support the most alluring schemes.

It would seem as if Parliament almost regretted passing this law in a moment of panic, because eight years later a Select Committee, after turning the subject inside out, recommended "that self-contained locomotive coaches (or engines) not exceeding 6 tons in weight, making no sound from the blast and consuming their own smoke . . . be permitted to travel at the ordinary speed of vehicles, and only subjected to the same restrictions as such vehicles." It was a discreet recommendation, but it took nearly twenty-three years to carry it into legal effect!

While Britain appeared determined to prevent the realisation of the horseless carriage era, other countries assumed a more sympathetic attitude towards the scheme and encouraged inventive fertility. In 1865 a French investigator named Lenoir brought out a motor using gas as fuel, and in which the gaseous charge was ignited by an electric spark, essentially for the propulsion of road-carriages. This was the first internal combustion engine.

The Lenoir engine attracted considerable attention throughout the world, and incidentally it induced a German engineer, Siegfried Markus, to turn his attention to the creation of a motor-driven vehicle using an engine of this type. Markus took an ordinary two-wheeled hand-cart, upon the axle of which he mounted two flywheels. Beneath the baseboard he installed a motor using benzine as fuel. A two-wheeled fore-carriage was tacked on. This served for steering, movement to the right or left being effected through a small handwheel and worm-gearing.

This car was completed shortly after Lenoir's motor made its appearance, and there is no doubt but that the Frenchman's novel engine induced Markus to contrive a motor working upon a similar principle. Be that as it may, Markus completed his vehicle and ran it freely upon the roads, generally selecting the cloak of night for these novel trips owing to the crowds who were wont to collect to see the new sensation. At last these gatherings of curiosity-provoked sightseers reached such proportions as to bring about a cessation of traffic. The result was that the police intervened and compelled Markus to take his car off the roads because it constituted a public nuisance. This car is still in preservation, being an honoured relic of the Austrian Automobile Club in Vienna.

The field of experiment moved from Britain to France, and the French experimenters worked diligently and incessantly towards the realisation of the idea. A decided impetus was imparted by Gottleib Daimler's internal combustion motor with enclosed crank and flywheel, which was a distinct improvement upon that devised by Lenoir. But prior to the appearance of this engine an English inventor, Edward Butler, undeterred by restrictive legislation, succeeded in evolving a practical and efficient petrol cycle. What is more to the point, this machine incorporated all the fundamental features considered as essential to-day, such as the float-feed spray carburettor, the magneto dynamo, and also the high-tension ignition system with accumulator and coil, which system, by the way, is undergoing a spirited revival in certain American motor-manufacturing circles at the present moment. This machine was designed to use the most volatile oil products as fuel, and, indeed, paved the way to the general adoption of petrol for this purpose.

In the construction of this car Butler experienced his full share of the difficulties which assail an inventor when attempting to produce something entirely new. His two cylinders, only 2¼ inches in diameter, had to be fashioned from phosphor-bronze because cast-iron cylinders of such small dimensions could not be obtained for love or money. A Clerkenwell clock-maker had to be induced to make the gear wheels used in the epicyclic driving gear which he incorporated, while London had to be ransacked for rims for the wheels.

Butler was persuaded to build his machine by the circumstance that a syndicate undertook to place the invention upon the market. But shortly after its formation a minute examination of the Red Flag Act revealed the fact that by no manner of means could this statute be evaded. It was one of those few instances of legislation through which the proverbial coach-and-four could not be driven. Somewhat mortified by this discovery, the syndicate resolved not to provoke public hostility or to incense the stern majesty of the law, and abandoned the idea.

In France things were now commencing to move rapidly, and the motor-car was beginning to assume the semblance of something practical. Dunlop gave the new locomotion a decided spurt by introducing, or re-inventing, the pneumatic tyre; this type of tyre made its first appearance in 1870, and was the product of the inventive fertility of Thompson. But, although the petrol motor may be said to have been brought to a practical stage, there was a strange reversion to steam. Serpollet was responsible for this revival, and many carriages after his designs were built. Indeed, as a result of his interesting reversion, he may be said to have placed the steam-driven automobile upon a firm basis. Although the petrol vehicle has made enormous strides up to the present time, it has not completely driven its rival—steam—from this field of utilisation.

But it is doubtful whether motoring would have advanced so rapidly had it not been for the tonic of competition and racing which was introduced in France. In 1894 the first race over the highroads was held—from Paris to Rouen, a distance of 80 miles. This competition served to rivet public attention upon the possibilities of motor traction and to foreshadow that, no matter what opposition might be launched against the new idea, it had progressed too far to be killed by public opinion.

After Butler's abortive effort to circumvent the drag of the Red Flag Act, little attention was devoted to the project in this country until 1895. Then an English gentleman, Mr. John Henry Knight, a well-known engineer, once more took up the cudgels on behalf of British effort. He had previously built, some years before, a steam-car, but now he embraced the latest idea—the oil engine. He had already invented an engine of this type, which had proved a distinct commercial success, and he decided to adapt it to a three-wheeled carriage. This was subsequently converted to the familiar four-wheeler to secure greater safety. While this car could not be called a "flier," it aroused attention by notching 8 miles an hour, which was twice the limit allowed by law.

It was this car which played a prominent part in bringing about the repeal of the iniquitous Red Flag Act. One day, while joy-riding at some 6 miles an hour, a policeman swooped down upon Mr. Knight. He was prosecuted with the utmost rigor of the law upon two indictments, to wit, not having a traction-engine licence and not being preceded by a man with the red flag. Fortunately, he fell into the hands of somewhat enlightened magistrates, who, having to fulfil the law, considered justice was adequately met with a fine of half a crown and costs upon each summons!

This prosecution led to a far-reaching outcry against the handicap under which British inventors were labouring in a new field of endeavour, the limits of which could not be foreseen, while the advances recorded in other countries, where such farcical legislation did not prevail, were considered detrimental to British industrial supremacy. The *amour propre* of the nation was touched in a very tender spot—we were lagging behind our trade rivals. The popular slogan had its effect, the ponderous machinery of the law was set in motion, and under the spurring of public opinion was hurried so effectively as to bring about the repeal of the hated Act of 1865 within a few months.

Freed in 1896 from all its fetters, British inventive skill and activity went ahead with unusual vigour. Factories were founded, but for the most part were compelled to rely upon the products of foreign brains, British initiative having been strangled for so long. Britain's manufacturing entry into the arena brought about a general speeding-up in all directions. Our determination to make up the leeway created such an impression upon our competitors that they redoubled their efforts to keep ahead. But we had set the pace, and it was hot. It was not long before British cars began to assert themselves in the great Continental races and competitions, and a decisive achievement for British motor-manufacturing prowess was recorded in 1902 by Mr. S. F. Edge winning the third contest for the Gordon-Bennett trophy over the 329 miles between Paris and Vienna, with an average speed of 34.3 miles per hour.

After gaining a foothold in what may be described as the pleasure-car market, British endeavour turned its attention to the commercial field. Here, owing to the wide diversity of the requirements to be fulfilled, almost illimitable scope was offered. To-day the production of cars essentially for commercial purposes constitutes the sheet anchor of the British motor-manufacturing industry. Every possible field of application has been invaded, and at the moment a spirited struggle is raging between the internal combustion motor-driven vehicle and electricity for supremacy. This rivalry is more pronounced in what might be described as public-service facilities. The motor-bus is faster and more mobile than the electric tramcar. The public has not failed to recognise this advantage, and is extending a greater measure of favour to the former than to the latter. This rivalry is particularly pronounced wherever the two systems are running directly side by side.

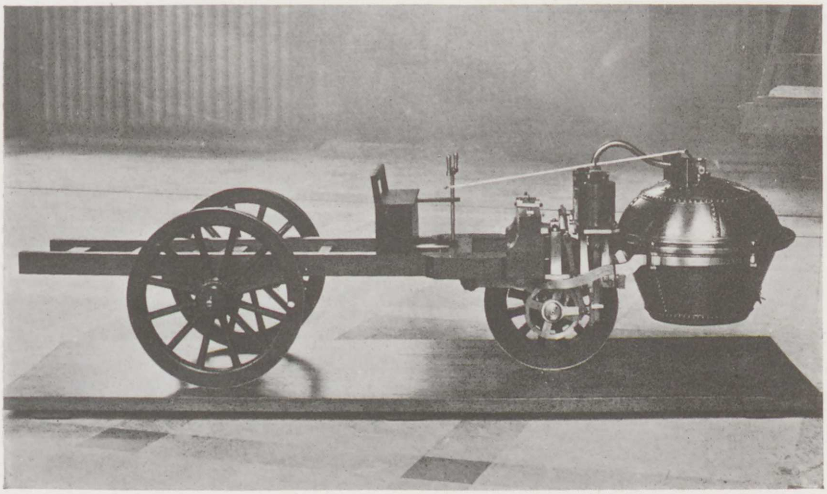
The internal combustion engine has assured the speediest form of locomotion upon land, in the air, and upon the water. In the first-named instance it has long since surpassed the train, which was considered for so long to be invincible in this connection. Upon the water it has relegated the steam-driven craft to second place by notching over 40 miles an hour. In the air the highest speeds ever attained by mankind have been rendered possible by this engine —2½ miles per minute!

It was this motor, moreover, which first brought submarine warfare within practical limits. Previous to its perfection the submarine had been regarded somewhat as a phantasy. True, at the moment, the petrol motor has been superseded in this service, but only by a younger brother—the Diesel oil motor—

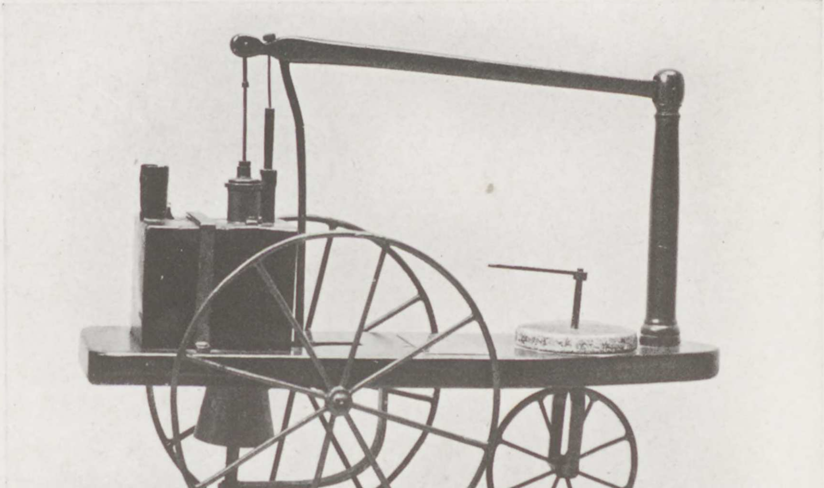
which has the advantage of working upon a less volatile and consequently safer liquid fuel.

Twenty years ago the horse was supreme upon the highways. To-day it is rapidly becoming relegated to the limbo of things that were, not in one, but in all its realms of application. The humble toiler favours the motor-bus for expeditious transportation between his home and the field of his labours. The taxi-cab has wellnigh driven its horse-drawn contemporary from the streets. The farmer employs the motor for breaking his ground, sowing and garnering his crops, hauling them to market, and for the conveyance of any and everything necessary to his calling. In mining districts, where the horse and mule have packed tediously and slowly over barely distinguishable trails, roads have been laid out to permit heavy vehicles to pass swiftly to and fro. The cyclist no longer pedals hard and laboriously to enjoy a rural excursion, but allows the high-speed engine to work for him and to carry him greater distances in less time. The enterprising tradesman dispatches his goods to customers by the commercial vehicle, which not only enables him to fulfil "express delivery," but provides him with the means to serve throughout a wider radius with less staff and conveyancing facilities, as well as rendering him independent of the railways. Indeed, to recapitulate all the fields in which the motor-car has achieved a decisive conquest would be wearisome.

Nor is the motor-car a luxury for the privileged few. Standardisation of parts, the more extensive employment of automatic tools, is enabling the cost of manufacture to be reduced to such a low figure



CUGNOT'S STEAM DRIVEN CARRIAGE
The first self-propelled road vehicle.



MURDOCK'S MOTOR CAR
The first built in England (circa 1781).

as to bring a serviceable vehicle within the reach of a far wider public than was conceived to be possible even ten years ago.

In this particular realm of endeavour the United States is playing a prominent part. This is due in the main to one man—Henry Ford. He is probably the most picturesque figure in American motor-manufacturing circles. He first aroused public attention by fighting might and main Henry Selden, who claimed to be the American inventor of the petrol-driven car. While the majority of manufacturers were disposed to accept this contention, a few—at the head of whom was Henry Ford—thought otherwise. Thousands of pounds were squandered upon litigation, but with abortive results, from Selden's point of view. Indeed, litigation was so drawn-out that the patent expired, from the effluxion of time, before a final decision could be reached. But Ford had the satisfaction of knowing that he never paid a penny in tribute to a patentee whom he always considered unable to establish his contentions.

Upon the conclusion of the campaign in the courts, Ford decided to embark upon the manufacture of cars upon an extensive scale, so that they might be sold at a low figure. He summoned his most successful agents to his office one day to explain his idea. But the agents could not see eye to eye with him. At last, rising from his chair, he passed to the window and beckoned his audience. It flocked round the window and followed Ford's pointing finger. It was levelled at a woman working a sewing-machine at a window across the street.

"Now, how much do you think it would cost me to make a single model of that sewing-machine ?" he inquired.

"About £20, I should say," ventured one of the agents, who was an engineer.

"But how much has she paid for it ?"

"Not more than £4," was the rejoinder.

"Then if it would cost me £20 to build the machine and she can buy it for £4, what is the reason ?"

"Oh, sewing-machines are turned out by the hundred thousand !"

"Why ?"

"Because all parts are standardised, and each part is made by the hundred thousand. Naturally, if you build sewing-machines on such a scale, you can sell them for £4 apiece and then make a handsome profit," commented another agent.

"And if sewing-machines can be made in that manner, why not motor-cars ? The parts can be standardised and made upon a similar scale," pursued Ford. "Can you tell me why they shouldn't ?"

"No—if you can find the market for the cars !"

"Well, I intend to create that market. For every man who can afford £400 for a car, there are scores who would be willing to lay out £100. Those are the customers I desire. Now listen. I am going to build a factory and equip it with the best labour- and time-saving tools I can find. I am going to build motor-cars, not by the dozen or score, but by the ten thousand. When I bring my factory to full productivity, I shall be able to turn out 100,000 cars —or more—a year. Now, you've got to sell them. You will not find the job so impossible as you seem inclined to imagine. Get the confidence of the public.

Induce them to realise that a motor-car can be built like a sewing-machine, and you'll win out."

The agents were so impressed by the manufacturer's enthusiasm that one-half of the first year's output was purchased there and then. They assumed the responsibility for their disposal. What is more, their experience vindicated the manufacturer's imagination to the full. The public were magnetised by the cheap car, and the first year's production fell short of the demand. Within two or three years of the completion of the factory, 75,000 cars were turned out and sold during a single year, and the 100,000 mark has long been passed.

While British manufacturers have not yet succeeded in emulating the American producer's example, there is every indication that decisive effort in this direction will be made. It would not be surprising if the tables were turned upon the imaginative and energetic American manufacturer. He may yet experience the full effects of being undersold by a British car turned out by the hundred thousand. There is a prevailing opinion that the Ford car is the cheapest vehicle upon the American market. This is a fallacy. In that country competition for the market of the cheap car is only just commencing.

In Britain this era has not begun ; it has been postponed from circumstances over which the manufacturers have had no control. When the whole-hearted assault is made to capture it, then a new era in the history of the motor-car will have dawned, and the self-propelled vehicle will come to be regarded as more indispensable to our social and industrial welfare than it has been hitherto.

CHAPTER XV

Animated Pictures

If one were to ask what constitutes the most popular form of entertainment at the present moment, the answer would come unhesitatingly—the cinema. No other means of amusing the public—whether it be to beguile the tedium of an idle half-hour or the whole of an afternoon or evening—has ever secured such a firm grip upon the public fancy. Moreover, its influence is not confined to any one class of the community. It appeals as strongly to the rich as to the poor, and entertains the old as triumphantly as it does the young, while it provokes as much delight among the unsophisticated natives of the dark countries as it fascinates the developed minds of the centres of civilisation.

The general impression prevails that the cinematograph is a product of the past fifteen years' ingenuity. But this is an error. Animated pictures were shown half a century or more ago, when, according to the records of the patent offices, the fundamental principles governing the idea were first perfected. But the pictures were exceedingly crude, and consequently failed to meet with popular appreciation. This was not the fault of the invention. It failed because the photographic art had not been advanced sufficiently to enable it to be brought into service in this new field.

In order to secure the illusion of movement by means of pictures two features at present are recognised as being absolutely indispensable. These are respectively a device for carrying the fabric or base upon which the pictures are mounted or printed, and a means whereby each picture may be held stationary for the fraction of a second before the lens. An apparatus embodying these fundamental characteristics, without which, so far, it has not been possible to produce animation by photography, was devised in 1861, and even anticipated the cinematograph or kinematograph in name, by being known as the "Kinematoscope." Four years later another worker introduced an improvement for moving the carrier which advanced the art, which was then in an extremely immature and tender stage.

But it was February 5th, 1870, which really ushered in the era of the cinema as we know it to-day because on that date was given the first public entertainment of this character. The Academy of Music in the city of Philadelphia, was hired for the purpose, and an audience exceeding 1,500 people witnessed the silent animated pantomime as revealed by photography upon the screen.

The "show" was given by Henry Heyl, and it aroused considerable attention owing to the striking life-like character of the pictures. He gave his apparatus a weird name—the "Phasmatrope"; but really it was the parent of the modern machine. Possibly the apparatus and its method of operation might be described as a combination of the magic-lantern, which has been a popular form of juvenile entertainment for centuries, with the modern moving picture machine; but by whatever name it may be called, it succeeded in its essential purpose—it conveyed life-like photographic representations. What is more, it represented the first proved illustration of synchronising movement with sound.

Those were the days before the flexible celluloid film, and when the wet process still prevailed in the art of photography. Consequently Heyl's achievement was somewhat remarkable, and was a wonderful example of unremitting patience, skill, and perseverance. Each picture was reproduced separately upon a glass plate from which a glass positive, somewhat reminiscent of the lantern slide, was prepared. But the pictures were taken at such brief intervals that when thrown upon the screen at the accurate speed, rhythmic animation was secured. The audience was moved by one series which portrayed two accomplished waltzers, and the perfection of the production was brought home by the fact that their actions synchronised absolutely with the tempo of the waltz music played by the orchestra.

Heyl's apparatus was somewhat complicated. It comprised the lantern set within a revolving frame wheel placed in a horizontal position. The rim of this drum was so divided into spaces that each would receive one of the glass plates or slides. The wheel was charged to its full capacity with these slides disposed in correct sequence, and then revolved at the speed necessary to secure the illusion of movement. When a slide came before the lens of the projector it was held stationary for the fraction of a second. Then it moved forward as the light was obscured by a shutter which, moving to and fro, interrupted the rays of light while the one picture was moved from its position before the lens to allow its successor to come into position, in precisely the same way as the light is cut off between each picture in the apparatus of to-day. When the picture had passed the lens it was withdrawn from the frame and another inserted, this cycle of operations being continued until the last picture in the series had been projected upon the screen.

Heyl even introduced humour into his novel entertainment, the subject which provoked the audience to mirth being an excited figure of "Brother Jonathan" delivering a protest. In this instance an associate concealed behind the screen spoke the words, and in tones he would have assumed had he been acting openly before the audience. The expressions and the lip-movements were observed to be so coincident with the utterance of the words that the audience was moved to enthusiastic applause.

But Heyl's invention was premature and too unwieldy to be considered a commercial undertaking. It proved a popular "turn" wherever it was shown, but its success was short-lived. Still, Heyl succeeded in exercising other minds who were impressed with what he had accomplished, noted its appreciation by the public, and who immediately embarked upon the study of ways and means of achieving a similar end more effectively, with greater simplicity, and commercially.

Yet Heyl had merely adapted a toy which has ever been popular in the nursery to the exigencies of entertainment for one and all. The "Zoetrope" is well known, and the young mind as he peeps through the vertical slits of a horizontal drum upon the white inner surface of which grotesque figures in different positions are printed, ever wonders at the appearance of movement which is imparted to the pictures when the drum is rapidly revolved.

But there is one outstanding feature which must be borne in mind in connection with Heyl's achievement. His series of pictures were taken from one point of view, as they are to-day. This is the outstanding difference between what he did and that of the next man who gave a decisive impetus to animated photography, and whose name is the most prominent in connection with these early efforts.

Muybridge, the experimenter in question, set up a series of cameras in a long line at predetermined distances, the shutter of each of which was actuated as the moving subject passed. Muybridge embarked upon his experiments with a view to elucidating pictorially certain debatable points in connection with the movements of animals. He did not aspire to their projection, as did Heyl, so much as the study of successive photographic prints. Subsequently, however, he did prepare glass positives or slides for projection upon the screen, the apparatus he designed to consummate this end being somewhat similar in its broad principles to that evolved by Heyl, and to which Muybridge gave the name "Zoöpraxiscope."

While Muybridge was concerned with these later experiments another American inventor, Thomas Alva Edison, was perfecting an appliance for photographically portraying life-like movements, and it made its appearance in 1889. The apparatus, which was christened the "Kinetoscope," recalled in its general features the device which had appeared in 1861, because it belonged to what is known as the "peep-hole" class of machine. That is to say, only one person could witness the movement at a time, and that by applying the eyes to the aperture in the cabinet provided for the purpose, the viewer saw the pictures pass in rapid succession. But Edison's "kinetoscope" represented a decided advance upon any machines for portraying animation by photography which had hitherto appeared, because in this instance the pictures were no longer printed upon glass. The transparent images, 1 inch in width by ¾ inch deep, were printed upon a long band of celluloid, which was coiled to and fro around drums to form an endless length.

The "kinetoscope" was rendered possible by two inventions which had appeared a short time previously—two inventions of such far-reaching import as to revolutionise the whole art of photography, not in one phase, but in all its aspects. The shortcomings of glass had long been appreciated. It was fragile, bulky, and weighty. Many efforts to discover an efficient substitute were made, but they proved abortive. It was not until J. S. Hyatt, an industrial chemist, announced his invention, celluloid, that any progress could be recorded. Here was an ideal base to take the place of glass. It was extremely light, could be accommodated in small space, was inexpensive, and although highly inflammable, possessed so many other advantages as to recommend its utilisation for photographic purposes.

But the celluloid available was not suited to photography. It had to be adapted to the new requirements, and success in this direction is entirely attributable to two diligent American workers, Messrs. Walker and Eastman. They finally prepared a celluloid base, as it is called, which, when covered with the sensitised emulsion, could be employed either for negatives or positives.

The perfection of this idea served as the key to another problem upon which they had long been engaged. This was the perfection of a camera in which the pictures, instead of being taken upon single glass plates, might be received upon a length of celluloid, and in such a manner that, after a picture had been taken, the exposed section might be wound on a drum to bring a succeeding area of the unexposed surface into position for exposure. It appeared a simple problem, but as a matter of fact it was one bristling with baffling perplexities. But perseverance brought its due reward, and in 1888 appeared the first camera of this type with roll holders carrying a sufficient length of film for one hundred exposures.

Eastman's apparatus, which to-day is universally known as the "Kodak" camera, naturally suggested animated photography. If a length of film could be introduced into a camera capable of receiving one hundred successive pictures of the accepted size, why could not the camera be adapted to take a length of film sufficient to receive several hundred pictures of smaller dimensions? This was the issue as it occurred to Edison, who forthwith reduced his idea to practice. Although he succeeded, it was quite apparent that his invention was based upon the Kodak camera, which was capable of being adapted to the self-same duty with certain slight modifications. Indeed, it is possible to take a certain class of moving pictures with the Kodak even to-day with distinct success, although they cannot be easily adapted to projection because the dimensions of the negative exceed the gauge of the cinematograph film, with the result that if projection by the ordinary apparatus were desired, reduction of the positives to 1 inch wide by ¾ inch deep would be necessary. Although this is not an insuperable task, it is one of complexity, while, of course, the item of expense has to be borne in mind.

The "kinetoscope," however, failed to arouse the public. The fact that only one person at a time could witness the scenes portrayed was inimical to its success. Machines found their way to all parts of the world, but to a great extent they constituted merely sideshows in the "gaffs," and worked upon the penny-in-the-slot principle. Another objection to the idea was the comparative dearth of pictures, the output of films being relatively small, and, as all were made in America, the invention somewhat languished.

The novelty met with greater popularity in Britain than in any other country, because one enterprising British engineer possessed too much energy and initiative for the Americans. This engineer, Mr. Robert Paul, discovered that for some inexplicable reason or other Edison had failed to protect his invention in Great Britain. This was a startling surprise, and one which was quite unexpected, because it enabled anyone who felt so disposed to make and to sell the kinetoscope. Mr. Robert Paul seized the opportunity, and in a short while built up a considerable business in all parts of the world.

Somewhat chagrined at this turn of events, an effort was made by the American interests to thwart Paul's success by the refusal to supply any further films to anyone using aught but the American-built kinetoscope. Even this step was countered by the enterprising Englishman. If America would not supply films for the needs of his customers, then he would make his own films to avoid disappointment. What is more to the point, he put the threat into execution with little delay, and was soon rendering not only this country but other countries independent of the American product. The British films met with appreciation because Paul offered a wider variety of subjects than the American producers, with the result that the American trade was speedily reduced to negligible proportions.

Mr. Robert Paul, who originally had taken up the manufacture of the kinetoscope as a side line in his business, now threw himself heart and soul into the subject. He realised the shortcomings of the kinetoscope from the very first. If only it could be rendered possible to throw the pictures upon the screen in such a manner that several hundred people might witness them simultaneously, then the animated photographs would be more likely to command popular approval. He laboured long and diligently to this end, and finally, after many exasperating difficulties had been surmounted, succeeded in his object. The first public performance of moving pictures before a large audience created far-reaching excitement. It was only too evident from the reception which was accorded that the cinema had now come to stay, although no one, not even the most enthusiastically optimistic, ever dreamed that it would secure such a hold upon the public or would develop into the complex, huge, and far-reaching industry it is to-day.

While the British experimenter was toiling in his workshops, a French inventor was labouring to a similar end. Neither knew what the other was doing, and, curious to relate, both succeeded in their respective, though common, enterprises about the same time. The French inventor was M. Lumière. He had similarly acquired a kinetoscope shortly after it made its appearance upon the American market, and he too had been impressed with its disadvantages and limitations. Consequently he strove towards the perfection of ways and means to throw the pictures upon the screen before a large concourse of people. The success achieved in France was quite as pronounced as that recorded in this country.

It must be remembered, however, that France had been associated with this new art far more intimately than any other country. A distinguished scientist, Monsieur Marey, had realised the possibilities of chrono-photography, as it was called, as a scientific instrument for the analysis of motion, having been attracted to this issue by the result of the British worker Muybridge. Marey was forced to use glass plates, the celluloid ribbon being unknown at the time he first embraced the subject, and he constructed many interesting and highly ingenious apparatus to enable him to fulfil the objects he had in view. He even took a series of successive snapshots upon a single glass plate, but the pictures were not separate as in the latest development. They overlapped in some instances, so that the plate contained twenty or more successive pictures, which were then printed in the usual manner for examination. He also built a photographic gun, in which the pictures were taken upon segments of a disc, the gun being pointed from the shoulder at the object as if firing were contemplated, while the motion of the trigger actuated the shutter mechanism.

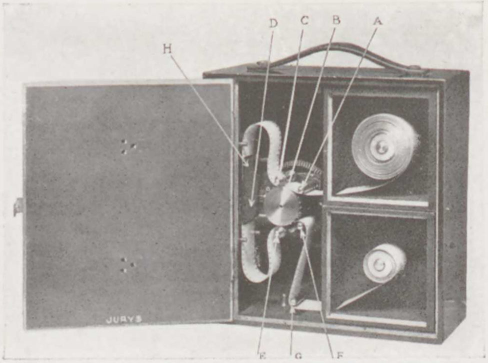
Marey achieved some beautiful scientific results and shed considerable and valuable light upon the subject of motion, which was his especial study. He even founded an institute in Paris, which is still in existence, and in which the class of work he initiated is still pursued. This institute has since become regarded as the home of scientific cinematography, and the laboratory is famous for the many ingenious appliances which have been contrived to enable special lines of investigation to be carried out. Incidentally it may be mentioned that many of the ideas which have been worked out at this laboratory expressly for scientific purposes have been adopted by the commercial picture producers. The latter were compelled to popularise the subjects in order to make them appeal to the public taste. Under these circumstances the Marey Institute, which is unique, may be considered as the Home of Cinematography in more senses than one.

The French inventor described his apparatus as the "Cinematograph," as a distinction from the Edison "kinetoscope" and its predecessor the "kinematoscope," while the English inventor, Robert Paul, christened his apparatus the "Animatograph" for a similar reason. There was every reason why such should be done, because the Anglo-French achievements ushered in the moving-picture era as it is known to-day. These two distinctive names averted all confusion with peep-hole machines whereby only one person at a time could see the pictures. Subsequently, when the Americans produced a similar machine for projecting pictures in motion upon the screen, the apparatus became generically known as the "Kinematograph." Considerable discussion has arisen as to which of the two spellings is correct. The American is literally accurate, from the Greek root *kineo*, to move, but the French name is really a generic term or trade-mark, and so is equally correct. Indeed, the French method of spelling is generally upheld as a compliment to French efforts towards founding a new industry, and the contribution of that country to the success of throwing pictures in animation upon a white screen for simultaneous observation by a large audience. Both words, however, are generally considered to be unwieldy, with the result that the simpler and more explanatory American term "Moving Pictures" is universally preferred. As might be expected, this descriptive name has been still further condensed into "The Movies," or "The Pictures," which has become, from wide application, the accepted modern cognomen for anything and everything connected with animated photography.

Robert Paul's invention in Britain and Lumière's apparatus in France were speedily appreciated by the public as a new and novel form of entertainment. In this country it became a recognised item in music-hall entertainments, the re-portrayal of the Derby of 1896 in photographic mime, with all the fidelity and excitement of the famous race and course, setting the seal upon its future popularity. Probably no topical film has ever created such a furore as did this particular subject. Other annual events were treated in a similar manner, while simultaneously the miming of plays—dramas, farces, comedies, and tragedies indiscriminately—was taken in hand, and the appearance of them proved still more powerful magnets for the crowds. The public realised that the man with the moving-picture camera was able to treat his subjects far more comprehensively, and was able to maintain the illusion far more effectively, than his colleague of the theatre.

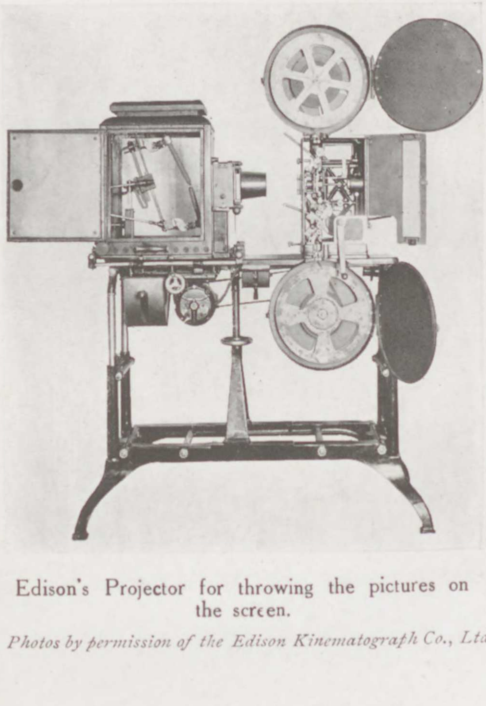
The limitations of the latter craft are very narrow and sharply defined. But with the moving-picture art there are no such trammels to hinder the faithful presentation of the idea in hand. A novel move was made by Mr. Robert Paul, who induced a well-known conjurer to perform his feats of legerdemain before the camera. While this work was in progress the operator suddenly conceived the idea that he could produce far more startling results by incorporating the art of trick photography. If a giant were required he was produced; if there was a weird manifestation in demand, it was supplied, and that without any great difficulty. To-day any conceivable effect, no matter how weird or wonderful, is obtainable. The impossible was rendered apparently possible, and these achievements exercised a weird fascination upon the public, who were—and still are—ever puzzling their brains as to how it is done.

Even to-day a clever trick picture is every whit as magnetising as it was five or ten years ago. It only needs to possess the novelty of freshness, either



THE CAMERA WITH WHICH MOVING PICTURES ARE TAKEN

A, C, upper sprocket pulleys. B, driving sprocket which carries the film forward. D, exposure window. H, gate through which film passes to be exposed. E, F, lower sprocket pulleys. G, pulley to guide exposed film into box.



Edison's Projector for throwing the pictures on the screen.

Photos by permission of the Edison Kinematograph Co., Ltd.

A section of kinematograph film (actual size). Each picture measures 1 inch in width by $\frac{3}{4}$ inch in depth.

in conception or the application of established features. Great Britain and France became recognised as the two great centres for producing pictures for the new form of entertainment. America was outstripped and left far behind. Indeed, the British and French films had a great vogue across the Atlantic. Enterprising Americans, who were sufficiently far-seeing to realise the coming of the boom which even then was looming, completed adequate preparations in advance to reap large fortunes.

As time went on the Americans perceived that they could profit from the production of pictures, and a speculating craze ensued. The man steeped in stagecraft, and who had scored big triumphs in the legitimate theatre, took up the young art, and by means of his knowledge was able to achieve bigger and more sensational results, which appealed strongly to the public fancy.

In Great Britain the infant was regarded somewhat as a pariah and outcast, who was endeavouring to filch business from the legitimate theatres by giving pictorial mime productions at a low price, so as to tempt the masses. As a result the man with knowledge and experience held aloof. The producers who were then in business, foreseeing the revolutionary development which was destined to take place, and some of whom—especially Mr. Robert Paul—were attracted more by the mechanical side as represented by the manufacture of apparatus, abandoned picture-producing entirely. Thus the art became virtually extinct in Britain, to the advantage of France and the United States, who have ever been spirited rivals, and it is only recently that a determined revival in these islands has become manifest. Now, owing to the eminent positions which other countries have achieved in this line, and in which Italy and Denmark have become established, the British producers are experiencing a hard, up-hill struggle.

Britain has none of the huge establishments given over to the production of pictures comparable with those in France or the United States. The latter country has prosecuted developments with its characteristic energy and upon typical American lines. After surmounting the difficulties pertaining to the technical side of the question, it began to tempt the favourites from the legitimate stage. At first their blandishments were treated with indifference, but it was speedily realised that bigger money could be earned before the solitary audience of one, as represented by the camera, than before two or three thousand people nightly in a theatre. The producers offered fanciful salaries, and were prepared to make long contracts. The bait proved so alluring as to be irresistible, and there ensued a big trek from the boards of the theatre stage to the boards of the studio, which has not even yet subsided.

This development arose from the sudden boom in picture palaces, which swept over the world with the virulence of an epidemic. Moving-picture shows were formerly given as items in vaudeville performances, or else halls were hired by the night, the moving-picture showman being closely allied to his itinerant colleague with the magic-lantern. But the shows were invariably enthusiastically patronised, the seating accommodation available being taxed to the uttermost.

This fact aroused the interest of an ambitious

Frenchman. Why not acquire or erect a building solely for the animated photographs, and devote the whole programme to the picture turn? He decided to make the experiment, and forthwith opened a palace exclusively for animated pictures. The idea caught on instantly. The public flocked to the new form of evening's entertainment, and, what was more, packed the house every hour it was open. Fellow-citizens were not slow to observe the fortune which their enterprising comrade was acquiring so rapidly, and forthwith picture palaces sprang up like magic, not only in Paris, but throughout the whole country.

The new craze crossed the Channel and conquered these islands just as completely. Then it seized the American people. The idea in those days was to convert empty shops into picture palaces. The cost of the transformation was small, necessitating a few dark curtains, seats, white screen, and a projector. Humble charges for admission became the rule in order to attract the masses. The demand for empty shops became insatiable, and in the American towns it was by no means uncommon to see a dozen or more of these converted amusement halls in a short street, all showing to full capacity throughout ten hours of the day. Then disused railway arches, forlorn factories—indeed, any building capable of being converted into a picture palace was taken and adapted to the new craze. The next step was the acquisition of larger buildings, to gut their interior, leaving only the four walls and roof standing, and then to introduce seating capacity to the best advantage.

While this move was in full swing more ambitious entrepreneurs sought more attractive pastures. Here a theatre was lying dormant and forgotten. It was rented, refurbished, given a glittering and brightly illuminated front, and lo! it blossomed out as a picture palace, the admission to which might be gained for the same nimble coin which would give one accommodation in the suffocating small converted shop. Naturally the comfort of a theatre made a greater appeal than the less pretentious and uncomfortable extemporised building a few yards away, especially as no heavier demand was made upon the pocket. The public flocked to the new centre, which soon enjoyed a new lease of prosperity. Other theatres and music-halls which were either closed or only being run at a loss went over from their designed business to the "movies," while even chapels which were languishing for congregations were bought up and their mission in civilisation radically changed.

Flushed with the success thus obtained, it was maintained by the more perspicacious adventurers that the "pictures" would safely and easily support buildings designed and built specially for the purpose. A wild scramble for the acquisition of attractive sites ensued. The existing buildings were torn down, and upon their ashes rose stately structures, invariably boasting ornate façades, and with their interiors scientifically set out so that everyone within could see the screen under the most favourable and comfortable—even luxurious—conditions. In the United States, where the boom reached its most frenzied heights, some of these theatres have cost as much as a quarter of a million sterling to build and to equip. Nothing but the movies are to be seen, and the establishments return handsome profits, despite the fact that in some instances the most luxurious seats can be obtained for a "quarter," while the greater part of the house is available to the humble "nickel" and "dime"—2½d. and 5d.—respectively.

Paris, the cradle of the craze, has never abandoned its latest love. Indeed, it possesses what is undoubtedly the largest building in the world devoted to the "movies." In Montmartre a huge building was run up several years ago for spectacular entertainments, exhibitions, circuses, and any other object for which plenty of space was required. But it was invariably closed for longer spells than it was open. A French picture producer, Monsieur Léon Gaumont, decided to acquire the building and to adapt it to the new fashion. His friends were somewhat staggered by his proposal, despite the fact that every picture palace in the city was enjoying great prosperity. Conversion in this instance proved a somewhat expensive task, owing to the vast size of the building; but the enterprising entrepreneur spared no expense, and in due course the "Hippodrome," as it was re-named, was opened. Those who had doubted its success, in view of its former chequered career, were compelled to revise their opinions. The wiseacres, when they gleaned tidings of the undertaking, shook their heads and sagely maintained that no one would go to the Montmartre to see moving pictures. But it is no uncommon circumstance for this picture theatre to be crowded with 6,000 persons, all enthusiastically following and applauding what is revealed to them upon the white sheet in photographic movement.

It was the boom in the picture palaces which stimulated the production of the pictures. The firms engaged in this task realised that they would have to embark upon extensive alterations to their studios to keep pace with the demand of the market. In America the majority of the huge producing establishments have grown from small proportions, and are still owned by private interests. In order to give some idea of the value of these undertakings, it may be mentioned that a short while ago a syndicate of financiers, anxious to participate in the new industry, approached one of the well-known firms and offered to buy the partners out. But the latter did not evince any desire to dispose of their property. The offers were renewed, and at last the partners stated their terms. They were £800,000 in cash and £400,000 in shares. They refused to take a penny less. Needless to say, the financiers were nonplussed. They had no idea that these establishments were likely to be so exacting in their terms; but they were enlightened when they were told that the business was yielding a profit considerably in advance of £100,000 per year, that the partners were then even contemplating extensions which would run away with more than £250,000, and that the plant as it stood at the time of the negotiations was worth a good deal more than £500,000.

The movement in America in the picture-producing realms has achieved its highest pinnacle through the initiative of one man, Carl Laemmle. A few miles outside the city of Los Angeles he has established, not a studio, but a city of 1,500 inhabitants, each of whom is a performer. Universal City it is called, and it is unique. It was brought into being merely to double the output of the previous producing

Photo by courtesy of the Nordisk Film Co.

A TRICK FILM

The "insect" in the flower is a dummy, and is made to move by the aid of the wires which are shown

By courtesy of Messrs. Pathé Frères.

A "GHOST" FILM

The effect is obtained by double exposure.

facilities, which yielded 25,000 feet of drama, comedy, farce, and tragedy per week.

The cost of production was rising rapidly, and in order to concentrate the interests the foundation of this community was taken in hand. Nearly 1,000 acres of land were acquired in the San Fernando Valley, and here have been built large laboratories for the technical staff, enormous workshops for tailors, carpenters, and the makers of other necessary properties, huge stages, miles of dressing rooms—in fact, every requirement for the production of pictures. Boulevards and streets have been laid out to form settings, while among the attributes may be mentioned a complete ranch, an Indian community where the Red Men may be seen pursuing their daily vocations, orchards, farmyards, a lake for water scenes on which a Mississippi steamboat plies, a complete railway two miles in length, complete with rolling stock, a large private zoo, and so on. If sea settings are required, motor-cars carry the actors and operators as well as directors to the adjacent shores of the Pacific. If a desert setting is in demand it is only a few miles distant in another direction, while the primeval forest is within easy reach to the north. Every conceivable natural environment is thus available, so that there is no waste of time in passing from point to point, while, the whole of the necessary company being to hand, no confusion or delay occurs. The flanking mountains and their woods form excellent battlegrounds, while the dank undergrowth fringing the river offers every requirement for jungle and lagoon scenes.

Within the city itself the streets are flanked by buildings, each face of which is different from the other. On this side the Orient is portrayed, while the reverse aspect gives the Occident. In addition to these buildings, shells are run up at a moment's notice, producing the facsimile of a building or street characteristic of any city or town in the world. A street of London, Paris, Bombay, or far-away Nome will be run up to-night, the scenes for which it is required will be filmed to-morrow, and the street will vanish the next night. Here a thrilling incident in a jungle story is being enacted with the indigenous wild animals, under the supervision of trainers, on the prowl. A stone's throw away a vigorous episode characteristic of the wild and woolly West is being played, while a Biblical battle is being waged on the adjacent hillside. On the big stage, the largest in the world, with a superfices of 80,000 square feet, fifteen plays can be in progress at one and the same time, from a trick picture to a domestic comedy in a suburban dining-room, from a sensational escape over a telegraph wire to the burglary of a millionaire's mansion, from a scene in the basement where the plumber is having a spirited tussle with a burst water-main to a dashing escape over a roof. The scenes are set side by side, and each camera, able to take in only what is within range of its narrow eye, is whirring merrily the livelong day. Some idea of the pressure at which the work is conducted may be gathered from the fact that at Universal City 1,500 subjects are filmed during the course of the year, from the short story, compressed maybe within 800 feet of film, to the serial story of twenty parts, representing in the aggregate from 30,000 to 50,000 feet.

The city is run upon the most up-to-date civic lines. There are schools for the education of the rising generation who take part in the plays, maintained by the company but under State supervision. There is a mayor and council, a chief of police—a woman—and full staff of mounted and foot constables, a Government Post Office, police court, jail, fire-brigade station and appliances, hospital and dispensary—in fact, every detail which is considered essential to the well-being of a modern community.

Only negatives are prepared at this city. They are rushed across the continent to New York, where the attached laboratories reel off the positives, the number of which varies from thirty-five to fifty, according to the subject and its demand. These are circulated among seventy-five exchanges distributed over the country, each of which serves one hundred theatres. By means of this organisation it is possible for a subject to be shown at no fewer than 7,500 theatres. The "City" reels out a steady 50,000 feet of new subjects per week, and this is maintained the whole year through. Universal City brings home vividly to one the enormous hold the moving pictures have acquired upon the public.

Yet the industry is only in its infancy. What the future developments will be it is impossible to foretell, but there is every indication that it is threatening the very existence of the theatre and music-hall. The mixed programme, which has ever been identified with the picture palace, will be partially substituted by the long film affording a complete evening's entertainment. Already this movement has attained a vogue in the States, while it is beginning to assert itself in these islands. Plays suited to this system of handling are of special production, and must be of an exceptionally attractive and spectacular character. The rights for a certain country are acquired in the manner of an ordinary play or novel, and it may be mentioned that high prices are realised over such transactions. Only a few months ago a British company paid £120,000 for the sole rights to show the productions of one American firm in these islands.

The purchaser of the rights sends the film on tour in precisely the same manner as a theatrical company travels from town to town. Theatres are rented throughout the circuit, the attraction is advertised in the approved manner, and it holds the building for the entire week or for a longer period according to its drawing power and the arrangements which have been completed. In America as many as twenty-five copies of one film have been on tour at the same time.

It must be remembered that the revenue accruing from such tours is far greater than that achieved by sending theatrical companies around a prescribed chain of theatres. Travelling expenses are trivial, three or four representatives being adequate, while salaries are equally insignificant. The running expenses at the theatre are also considerably lower. All things considered, such ventures—provided the pictorial fare offered is a first-class attraction—are certain to prove highly profitable, and more than one big fortune has been amassed within a very few months from such enterprises. In these islands the system has not become pronounced; it is just asserting itself. Thus we have had the picture portrayal of the well-known novel "The Clansman" presented under the title of "The Birth of a Nation" at Drury Lane Theatre. The circumstance that the Royal playhouse, which has witnessed many startling and spectacular productions—wonders of stage craft—should embrace photographic spectacle, surely constitutes a powerful vindication of the hypnotic attractiveness of the "pictures."

At the moment considerable rivalry is being manifested among the foremost producers of the world, irrespective of nationality, to eclipse one another's achievements. Twenty years ago a production could be staged for a matter of £5, while 300 feet of film was considered a "big" subject. To-day the sum of £50,000 is willingly incurred by the ambitious producer, while 10,000 feet or more of film may be consumed in recording the subject in 160,000 tiny pictures, measuring 1 inch in width by ¾ inch in depth, which flit across the screen at the rate of sixteen per second.

Despite the enormous strides which have been made, and the firm grip which the "movies" have secured upon the public fancy, the art is yet in its infancy. At the moment it is regarded essentially as an attractive form of amusement. It is hoped, and indeed maintained, that in the near future it will develop into an equally powerful educational force, but as yet there is no decisive indication of it superseding, or even supplementing, the textbooks in our schools.

CHAPTER XVI

The Sewing Machine

It is doubtful whether any invention has ever made such an enormous appeal directly to the household as the sewing machine. Certainly none can compare with it in the domestic circle as a time- and labour-saver.

One hundred, even seventy-five, years ago all sewing operations had to be carried out by hand, and in precisely the same manner as they had been done since the Dark Ages. The only difference between hand-sewing five or six thousand years before the Christian era, and at the beginning of the nineteenth century, was that a steel needle was used instead of one of bone or wood. While handwork possibly cannot be surpassed even to-day, it suffers from the grave disability of being exceedingly slow, the most skilful worker being unable to exceed a sewing speed of about thirty stitches a minute.

Yet sewing by the aid of a machine is by no means such a modern invention as one might suppose. Our grandmothers vividly recall the days of its first successful appearance and the sensational interest it aroused. But the women-folk of those times did not receive the proposal with open arms. There was a conspicuous scepticism of a machine ever being able to execute needlework as efficiently, neatly, tightly, and as perfectly as deft feminine fingers. Centuries of acquaintance with the ordinary needle had created a prejudice and an opposition to aught but handwork, which refused to be overcome in a single day. Indeed, the majority of homes would have little or nothing to do with the invention for many years.

It was industry, as represented by the factories, which forced the sewing machine into the household. Manufacturers of wearing apparel and other goods, for the production of which dependence had hitherto been reposed in the skill and dexterity of human fingers, recognised the many advantages accruing from mechanical sewing. By this means not only was the cost of manufacturing the articles reduced to a very low figure, but it was possible to increase the output of a factory to a degree never previously considered practicable, and that with a reduction, instead of an augmentation, in the number of the toilers. From this invention have sprung the immense and numerous workshops which specialise in the production of ready-made clothing for both sexes, as well as the cheap tailors and costumiers, which enable one to dress well and stylishly to-day at one-fourth of the money which our grandparents disbursed upon these necessities.

While a certain element of doubt prevails as to the date when the sewing machine was first built, there is conclusive evidence to prove that it was essentially a British idea. The very first patents ever granted for a mechanical sewing device were extended to a London cabinet-maker, Thomas Saint by name, in 1790. But it is not definitely certain whether Saint ever built a machine according to his designs, although it is only logical to presume that he did so, because his drawings are complete, and his specification is also comprehensive.

Whether Saint did or did not build a machine is a minor matter, because it does not affect the fact that he is entitled to all the credit of being the father of this product of ingenuity. His drawings include many of the fundamental features embodied in the modern machine without which, so far as knowledge has carried us, it would be impossible to execute the work which is accomplished thereby. That Saint's machine was perfectly practicable was proved many years ago by Mr. Newton Willows, who built a machine strictly in accord with Saint's conception and from his actual drawings. This interesting model is still to be seen in the South Kensington Museum. As a matter of fact, the London cabinet-maker, in his patent, described and illustrated three machines capable of being operated either by hand or power, one of which, be it noted, was intended essentially for the making of boots and shoes.

The similarity of the present-day sewing machine to that evolved by Saint is very striking in many particulars. There is the horizontal cloth-plate, the overhanging arm with a vertically working needle at its extremity, the "feed," working automatically between the stitches, and the cotton or thread wound on a reel carried on the arm. The most curious feature, however, is what may be described as the double needle—or, rather, two needles. Saint did not contemplate that the needle might be able to drive its own way through the material to be sewn, because he introduced a sharp-pointed tool, similar to an awl, which was moved mechanically, and made the holes in the fabric for the passage of the needle proper. This needle was provided with a simple notch instead of an eye to carry the thread.

By means of this notched needle the thread was carried downwards through the material to form a loop upon the underside of the latter. The loop and the material were then moved forward automatically a predetermined distance, when the next hole was bored to admit the needle, and another loop was formed as before. This cycle of operations was continued until the task was completed.

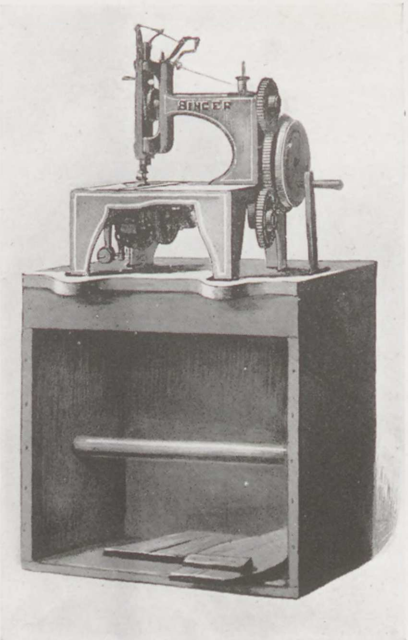
It will be seen that the stitch made by the Saint machine belonged to what is known now as the single or chain type. The method of operation was satisfactory within its limits. Saint, however, does not appear to have prosecuted the line of development which his fertility had indicated. At all events, there is no further record of his work in this field, because he never took out another patent connected with the sewing machine.

In the course of the next few years other inventors produced some entirely novel machines, but for some reason or other they were not appreciated.

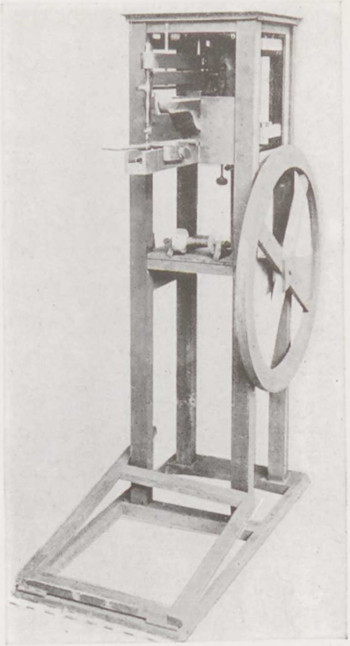
Then, in 1830, a French tailor, Barthélemy Thimmonier, of St. Etienne, brought out a sewing machine which also belonged to the chain-stitch category. This effort is notable for carrying only a single needle, pointed to drive its own passage through the fabric, and notched at one side to carry the thread. The loop, or stitch, was formed by the thread being wrapped round the needle, which withdrew it through the material. The latter then moved forward a certain distance to permit the needle to redescend. In this instance the loops forming the chain-stitches were made upon the upper instead of upon the under surface of the material.

Thimmonier spent considerable time and patience perfecting his machine, and then demonstrated it before a few financial friends. They were so favourably impressed that they forthwith advanced the ingenious tailor the necessary sinews of war to establish and to equip a factory. This enterprise met with such success that eleven years later eighty of these machines were at work. But the seamstresses and tailors did not view the new development with favour. Like those who had fallaciously construed Hargreaves' spinning machine into a threat against their livelihood and had promptly smashed the new-fangled idea out of recognition, so did the discontented French needleworkers raid Thimmonier's factory and destroy the whole plant.

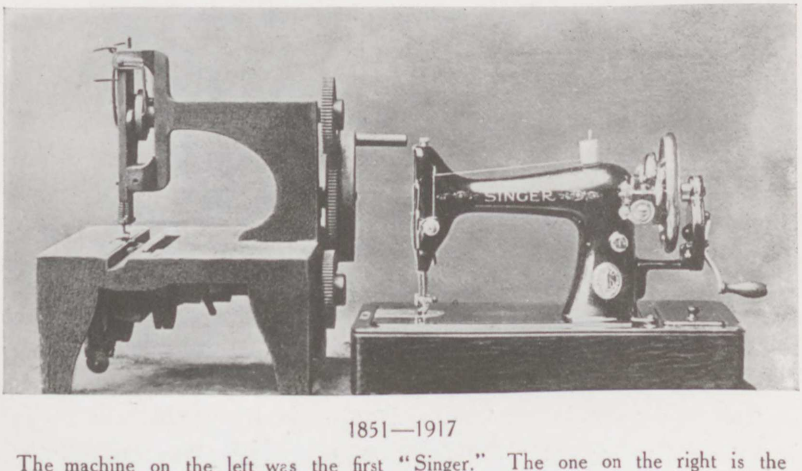
Thimmonier was not dismayed by this manifestation of mob violence and antagonism; it convinced him more than ever that his invention was certain of a great future. He built improved machines, one of which was stated to be capable of making 200 stitches a minute, and which was placed on view at the Great Exhibition of 1851. But apparently it attracted little if any attention. The inventor became bitterly disappointed at not receiving any further encouragement from his financial friends, who doubtless feared another outburst of frenzy among the needleworkers if they attempted to re-establish mechanical sewing upon a commercial scale. Moreover, the French tailor appears to have become involved in patent litigation in the United States. This was indubitably



The Singer No. 1, mounted on its own packing-case for working by treadle.



Model of the Thimonier machine, invented by a French tailor in 1830.



1851—1917

The machine on the left was the first "Singer." The one on the right is the Singer "99"—the latest model for domestic work.

instigated by the grant of a patent for a sewing machine to an American named Lye in 1826—the first recorded effort in this direction in that country. To-day, nothing is known about Lye's machine, because everything pertaining thereto perished in the flames when the American Patent Office at Washington was gutted in 1836. Thimmonier became a broken man through his misfortunes and the antagonism of his compatriots. He died in obscurity and poverty in 1859.

Thimmonier's success, interrupted summarily though it was, appears to have attracted the attention of other inventors to the possibilities of mechanical sewing. Among these were two Americans—Walter Hunt and Elias Howe. The period surrounding the early endeavours of these men is remarkable for the absence of details concerning their work, and this has led to considerable confusion and discussion, especially as the issue suffered additional aggravation because of the efforts of a British worker, Mr. W. Thomas. The defects of the chain-stitch, which had constituted the salient characteristic of all previous machines, were fully recognised. As is well known, such a stitch may be easily and rapidly unpicked. The severance of loops, here and there, enables the intervening section of thread to be pulled out with the greatest ease. What was wanted was a stitch which was free from this disability. Such an end could only be achieved by making each stitch a knotted unit, as it were. In other words, it became necessary to lock the stitch, and the perfection of the loop in this manner came to be known as the lock-stitch.

The nearest approach to success was achieved by an American, Walter Hunt, of New York City, between the years 1832 and 1834. With his machine, the peculiar feature of which was a single needle curved at its lower end, a lock-stitch was formed. The needle, carried in a vibrating arm, was threaded from the reel, penetrated the fabric, and thus formed a loop upon the underside. At this moment a shuttle carrying a coil of thread came into play, and passed through the loop, which, when the needle reascended, was drawn tight. In this manner the ordinary chain-stitch became locked. Hunt succeeded in enlisting the interest of a blacksmith, George A. Arrowsmith, of New Jersey, in his idea. The blacksmith, being asked to furnish funds to enable the machine to be perfected and exploited, and being of a speculative turn of mind, purchased one-half of Hunt's interest in the invention. Subsequently, by buying the remaining half of the interest, he secured complete control of the invention, and at a later date even employed Hunt's brother to build machines after this design, in which, however, certain modifications were incorporated. These machines were installed in a New York factory and evidently performed their work satisfactorily.

But Arrowsmith was a quaint character, and undoubtedly possessed strange opinions concerning the commercial exploitation of a new idea. A fortune was well within his reach, but he steadfastly refused to grasp it. He resolutely declined to take out any patents, and when, later, he was asked to explain this inexplicable attitude he replied:

"There are three reasons. In the first place, I had other business to attend to. Secondly, there was the expense of the patent fees. And thirdly, there would have been a great difficulty in introducing the machine to the public. At least three thousand dollars—£600—would have been necessary for the purpose."

There is every reason to believe that Arrowsmith was prompted to assume this hostile attitude towards patent protection from an experience which befell him in his attempt to push the idea. He doubtless considered that his forge and anvil, which offered a profitable livelihood, were more reliable than the sewing machine. The one was an established certainty, while the other was merely a possibility. The patenting fees could not really have persuaded him to such a course, because it would have involved an outlay of only about £12.

Arrowsmith only made one determined effort to push the machine. He suggested to his daughter, who was engaged in the business of corsetière, to introduce the sewing machine into that trade. But the daughter, after a conference with her friends, declined the suggestion " on the ground that the introduction of such a machine would be injurious to the interests of the hand-sewers. I found that the machine would be very unpopular and therefore refused to use it."

But Arrowsmith's attitude provided another worker with an opportunity which he seized eagerly. This was Howe, who filed his patent for a sewing machine on September 10th, 1846. Arrowsmith maintained afterwards that he had really anticipated Howe, and that he was entitled to protection. But his obstinacy brought its due reward : his machine failed to receive recognition owing to legal anticipation.

Howe is generally credited with having invented the modern sewing machine, but the honour is misplaced. No matter from what point of view his work may be considered, his machine lacked originality. The cardinal principles belonged to Saint, Thimmonier, and Hunt. There was not a detail which had not been known more or less for many years.

Howe simply assembled these separate pieces together in such a way as to produce a workable whole for which he was granted protection. The outstanding characteristics were: (1) a single needle pointed at its lower end and provided with an eye through which the thread from the reel was passed; (2) the oscillating shuttle carrying the independent thread, which was projected through the loop formed by the needle thread upon the underside of the material.

The fact that Howe could not be described as the inventor is borne out by the fact that although his patent was granted in 1846, it lay dormant in his hands for fully five years. Howe came to London and disposed of the British rights in his invention for a trivial sum to Mr. W. Thomas, a well-known corsetier in Cheapside, who, it appears, had previously been attracted to the sewing machine and who at that time was striving to complete essential perfections. Thomas had a flourishing business, but, being energetic and enterprising, was ever on the look-out for ways and means to increase his output. He was fully cognisant of the limitation of hand-labour, and was equally convinced of the powerful lever he would possess in competitive trade if he could only introduce a mechanical sewing system into his workshops.

The result of Thomas purchasing the British rights in the American invention was to bring the two investigators together. Thomas forthwith devoted his energies to rendering Howe's machine practicable, the inventor co-operating by entering the corsetier's employment. About three years' patient study and experiment were devoted to the machine, but the two were baffled by the lock-stitch problem. At last Howe, unable to make any advance beyond the point to which he had carried his idea, severed his connection with Thomas, and receiving the wherewithal, returned to his native country.

Thomas, determined not to be outdone, continued his work with the assistance of one or two of his other mechanical employes. Howe, in the seclusion of the tiny vessel ploughing the broad Atlantic, appears to have devoted his thoughts to the one absorbing subject, and at last, as if in a flash, the solution of the problem occurred to him. Simultaneously Thomas, by his diligence, also discovered the means to the end for which the two had been labouring for so long.

The situation is not quite clear. In some quarters it is averred that Thomas subjugated the difficulties almost immediately after Howe had left him, but, fearing the severity of the competition which would ensue in his particular business if the machine were extensively adopted, thus depriving him somewhat of the fruits of his endeavours, he decided to keep the invention to himself. It is stated that he built machines for his own workshops only, and in this manner secured a firmer, more profitable, and more extensive hold upon the corset industry, because he was thus in the position to manufacture the articles, by the aid of his machines, at a lower price and in greater numbers than his rivals who were condemned to hand-labour. Colour is lent to this trend of opinion by the fact that the British patent for the machine devised by Howe stands in the name of W. Thomas.

Thomas was unable to preserve his secret indefinitely. But once it became generally known, he abandoned the production of corsets and devoted his energies entirely to the manufacture of sewing machines upon a commercial scale, for sale to the public and to the textile and other trades by whom it was demanded. The Thomas sewing machine was certainly the first to invade the British household, although shortly afterwards Howe machines were also placed upon the market. During the early years of the sewing machine, it was by no means uncommon to see a Thomas and a Howe machine working side by side. As the virtues of the Thomas machine became more and more appreciated the demand increased rapidly, with the result that a highly prosperous new industry became established. For many years the Thomas invention dominated the market, not only in domestic circles, but in the heavier industrial fields for which it was eminently suited.

Howe, upon his return to his homeland, experienced many vicissitudes and was harassed sorely from all directions. The fact that he had merely succeeded in assembling various distinctive parts into a working whole caused his patent to be bitterly assailed. Long and expensive litigation followed. There was scarcely a detail which did not come in for its meed of attack, especially the needle with the eye at the point, which

Howe maintained to be one of the greatest features of his machine. This, it was pointed out, had been known and used in Great Britain for five years before the granting of the patent to Howe.

In fact, this needle really proved the crux of the sewing machine invention. In the early machines which were fitted with a needle, the eye was placed in the shank, or the opposite end of the needle. Consequently, considerable difficulty was experienced in forming a suitable loop in the fabric being sewn. This peculiar problem was solved by Howe's closely observant wife, who, noticing the difficulty, expressed wonder as to why an attempt was not made to place the eye near the point. In this way, she suggested, the thread could be carried well below, or above, the material according as to whether the loop were formed upon the upper- or underside of the material. The suggestion was subjected to test, and to the intense surprise of the investigator the supreme obstacle to success vanished.

Howe's patent was vigorously assailed for eight years, and the unceasing wrangling not only preyed upon his mind, but played such havoc with his slender financial resources that he was reduced to poverty. Then, just as everything appeared to be dead against him, and when it seemed as if the invention must be declared invalid for lack of novelty and owing to anticipation, the final courts in the United States gave a verdict in his favour. This was in 1846, by which time, owing to the ill-success which had attended his legal operations, a host of imitators had sprung up, and sewing machines were being sold here, there, and everywhere. The final verdict proved the turning-point in Howe's career. Every lock-stitch machine was condemned as an infringement of his patent, and he received a royalty upon every sewing machine manufactured in the United States, which eventually produced an income of upwards of £50,000 per annum. From poverty Howe was lifted into affluence. He accumulated a fortune of several millions before his patent, which was given an extension of seven years beyond the normal period, expired.

The decision in Howe's favour was so complete as to render it apparently impossible for a rival to enter the field without incurring the grave risk of being regarded as an infringer. As events subsequently proved, this was the stumbling-block to further decisive progress for some years.

One or two experimenters were decidedly ingenious in their efforts to perfect the sewing machine. There was one journeyman cabinet-maker, living in Pittsfield, Massachusetts, U.S.A., who, entirely ignorant of what Howe had done, devoted the whole of his spare time to building a machine which would prove successful in sewing pieces of fabric together. After considerable effort he succeeded in his endeavours and proudly exhibited his masterpiece, wrought in wood, to his neighbours. But they laughed at his work, considered him to be wellnigh bereft to attempt to sew by machine, and declared that, even if it did what he claimed, it would be impossible to compete with hand-work. This was certainly cold comfort for such an expenditure of energy and brains, but the wood-worker inwardly cherished diametrically opposite opinions upon the point.

One morning this industrious cabinet-maker, dressed in his Sunday best, set out for New York. His mission was a matter of considerable speculation among his fellow townsfolk, although there were many shrewd guesses as to the nature of his journey, judging from the extreme care with which he carried his parcel. The appearance of the man from the back towns in the streets of New York aroused the fleeting curiosity of passers-by, but he was immune against jocular remarks and sallies. He had been given an address in the city to which he was making his way with all speed. Reaching his destination he was ushered in, and after the preliminary greeting, nervously untied his parcel to withdraw the working model of his conception for a sewing machine.

At that time Howe's invention was the topic of conversation in patent circles. The new model did not arouse enthusiasm, because one and all were confronted with the bogey of prosecution for infringement of the master patent. Besides, Howe's machine had not proved a commercial success. Many had been purchased, but few had given satisfaction. Breakdowns were frequent, and the work was not executed with the nattiness demanded by the exacting housewife. Hence the lukewarm attitude towards the journeyman cabinet-maker from Pittsfield.

But suddenly the demeanour of the gentlemen whom he had approached changed to one of intense interest in the model. Examination of its details and the owner's comments concerning the method of working were followed closely. Then came an outburst of wild excitement. The man from the backwoods had conceived something decidedly novel. Without any further loss of time, all steps were taken to secure the utmost protection which the law allowed.

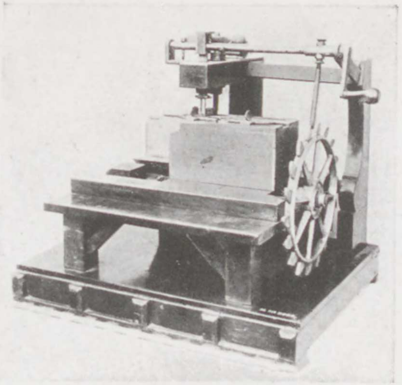
The unassuming cabinet-maker was A. B. Wilson, and the outstanding feature of his machine was the mechanism for moving the work forward automatically and accurately after each stitch had been formed. The movement became known as the "four-motion feed" or "drop feed," and it constitutes the greatest improvement which has been made in connection with sewing machines since Saint demonstrated by his drawings for the first time that mechanical sewing was possible. Indeed, every sewing machine worthy of the name to-day incorporates this feature. Upon the cloth plate, beside the point where the needle passes to penetrate the fabric, are one or two tiny serrated and moving surfaces. When a stitch has been formed these teeth rise a fraction of an inch to grip the surface of the material. Then it is moved forward the predetermined distance. This constitutes the second motion. The third motion is the descent of the teeth to release the fabric, followed immediately by the fourth motion, which is to move backwards preparatory to rising to grip the material once more. By the introduction of this feature Wilson rendered the movement of the material not only automatic, whereas hitherto it demanded to be moved by hand, but made the distance or movement of the material after each stitch positive and accurate. The labour involved in sewing by machine was appreciably decreased, inasmuch as by this means one merely had to guide the work. Needless to say, this novel mechanism met with the success which it deserved, and enabled the erstwhile journeyman cabinet-maker to become reckoned in the list of millionaires of his country, the machine incorporating these features becoming known as the Wheeler and Wilson.

Another contribution of far-reaching significance was made by a farmer living in Virginia. He happened to pick up a paper containing an illustration of a sewing machine at work. The picture fascinated him, and he traced the movement of the needle down to the moment when, with its thread, it perforated the cloth and disappeared from sight. What took place after the needle disappeared from view? The farmer spent many an hour endeavouring to puzzle out this point. True, an explanation of the subsequent movements was given, but they did not appear convincing to the man of the soil. So he cogitated and cogitated for hour after hour during the evenings. Finally, he decided to solve the riddle. The outcome of his experiments was the perfection of a revolving hook, which, placed beneath the cloth-plate, carries the independent cotton round and slips it through the needle-loop at the critical moment to form the lock-stitch. It was an ingenious device, which enjoyed a commercial success after the patent was granted in 1859, and which formed the outstanding feature of the machine known as the Wilcox and Gibbs, the latter being the name of the farmer responsible for the revolving hook.

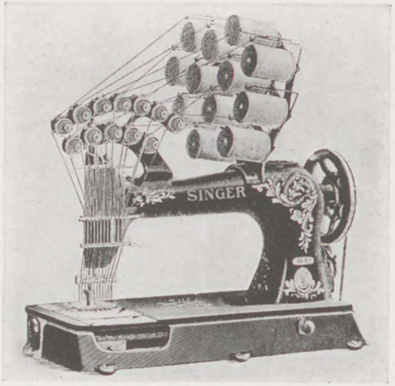
Yet, despite the activity among inventors between the years 1830 and 1851, the sewing machine had not met with complete favour. Indeed, so many imperfect inventions of this character were foisted upon the market to be proved unworkable, that deep-rooted suspicion against all and every mechanically sewing device and method was aroused. The turning-point in the success of the new idea came in 1851, and it was in the North American city of Boston, famous as the commercial home of the telephone, that the present successful era of the sewing machine was born.

A mechanic, who had tasted freely of the ups and downs inseparable from a journeyman's career, but who had a distinctly inventive turn of mind, was in the throes of the periodical fits of depression and impecuniosity which befalls every worker of this character. His adversity and the uncertainty of his immediate future induced him to think more seriously of his inventive bent. His thoughts brought him to the sewing machine, which at the time was a universal topic of discussion, not so much from what it had accomplished, but from the many failures which had been recorded, and the numerous impostors who had fleeced the unsuspecting housewives, as well as others who were attracted to the possibility of making fortunes by the acquisition of rights to sell the machines.

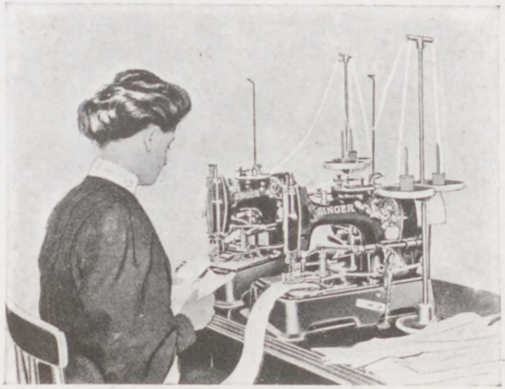
The mechanic was perfectly well aware of the manner in which Howe had secured a patent by assembling other people's individual ideas into a workable whole, and he determined to make an attempt in a similar line. He was a man of imagination and determination, as well as fertile of mind. He worked out his idea and decided to put it into execution. Alas! he was rich in thought but poor in pocket. In fact, he was penniless. But this disadvantage did not crush him. He knew two friends



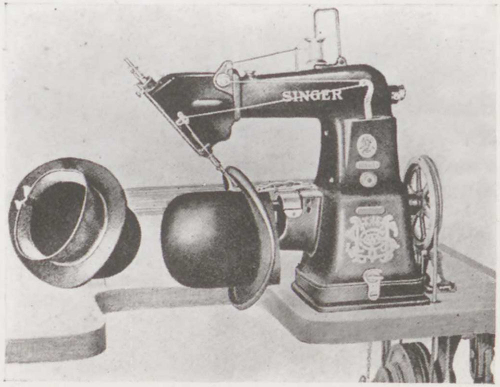
The first sewing machine invented by Thomas Saint, a British mechanic, in 1790.



Singer machine, with 12 needles and 12 shuttles, which can make 9,000 stitches per minute.



Two Singer machines for making button-holes, being manipulated by one operator at the same time.



Singer machine for sewing sweat leathers in bowler hats.

EVOLUTION AND ADAPTABILITY OF THE SEWING MACHINE

in the city, one of whom owned a successful engineering business. He went to them.

"I'm going into the sewing machine business, and I'm going to make it pay. I'm going to bring out a machine which can be built at a profit for forty dollars (£8). It's got to be made for that figure, or not at all."

"Well?" was the natural ejaculation.

"I want to get the money to prove that it can be done. Will you lend me forty dollars?"

The man to whom the appeal was addressed demurred, but he was so impressed with the vehemence of the mechanic's resolve that he did not point-blank refuse. His hesitation saved the day.

"Look here," broke in the engineer, turning to the third man, "you put up the forty dollars and I'll lend my tools and workmen. Singer can have the run of my shop. It's worth the risk, anyway."

"If we succeed," went on the mechanic, "there's millions in it. Once convince the public that they can get a reliable machine which will stand up to its work without the risk of the slightest failure, and sell it at an attractive figure, and they will run after it. I don't want you to give me the forty dollars. I'll borrow them and return the amount directly I get it back."

His insistence won the day, and the money at last was handed over to him. Thereupon he repaired to the machine-shop and set feverishly to work. All the parts were made either by himself or by the workmen whose services were placed at his disposal. Failure of this or that part to fulfil its purpose proved exasperating, but he would not be beaten. He scarcely ever left the machine-shop, denying himself food and rest. At last the machine was completed, and was ready for the test. But maddening failure loomed up. The machine could not be induced to work at all!

It was a fatal day. As the hours of evening crept on the workmen, disgusted, left him one by one, until at last only the companion who had financed the task remained with him. The failure was commencing to tell upon the mechanic, who was now all but a nervous wreck. His mind was too distraught to enable him to think clearly and calmly. The stitches were made, but they were a series of ragged loops. Strive how he would, he could not induce the machine to draw them tight. At last, as the clock struck midnight, the toiler threw down his tools with disgust and rose from the bench a broken man.

Silently and slowly the two threaded the streets leading to the rooms in the poor quarter which they called their home. The mechanic was scarcely able to walk, the reaction under the blow of disappointment revealing his extreme physical weakness, brought on by deprivation and anxiety. His companion was equally sick at heart, because he, too, was reduced to penury. All hope of retrieving the forty dollars which constituted his worldly wealth and with which he had financed the speculation had vanished.

The August night was hot and sultry, and the weakened toiler, on the verge of collapse, sank wearily upon a heap of timber stacked in the street. His companion sat down beside him. Not a word was spoken for several minutes. Then the two, gloomily and in disjointed sentences, discussed their ill-luck. Neither knew what to do to improve their joint fortunes. Presently the companion, who was more composed and was thinking deeply, remarked quietly:

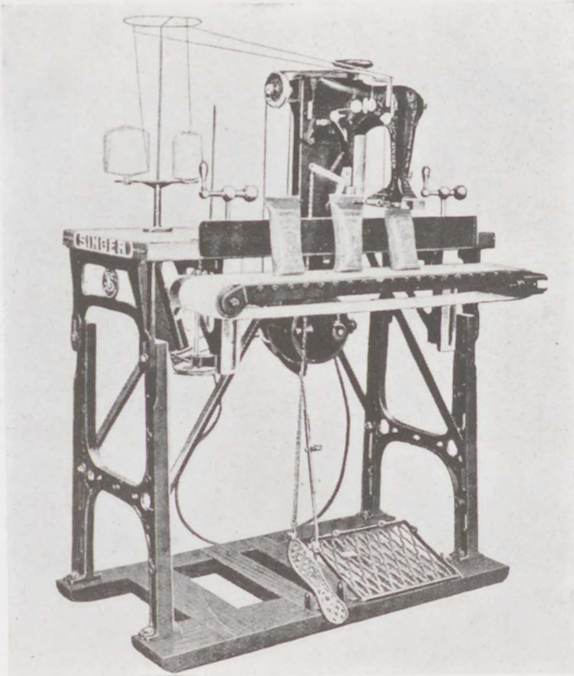
"Singer, it seems strange that the loose loops of thread should all be on the upper side of the cloth. Those underneath are quite tight."

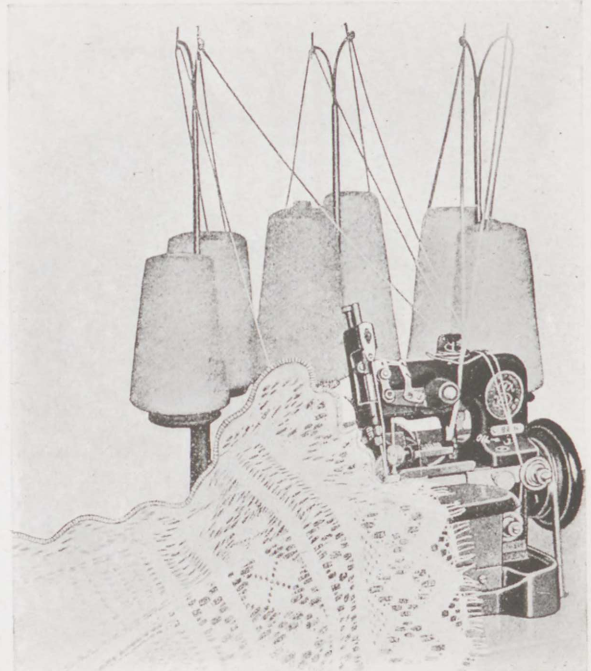
At these words Singer turned to eye his companion closely for a few seconds. His brows puckered, and then, suddenly, all signs of gloomy despair vanished from his face. Starting up he ran back toward the workshop, his companion hard on his heels, vaguely wondering what was the matter, and whether his friend's brain had at last given way under the strain. When he reached the workshop Singer was excitedly fumbling with the light, but his hands trembled so that he could scarcely turn the wick. Hastily picking up a screw-driver, the mechanic tightened one or two screws, and again turned the handle. The loops were becoming tighter. A touch here and a turn there to perfect the adjustments and—the work came through the machine perfect. Isaac Merritt Singer had produced the first practical sewing machine.

The next step was to take out the patents. True, there were no dominating new features in the new machine for which master patents could be claimed. But Isaac Merritt Singer had done at least as much as Howe. He had taken the groundwork which had been known for fifty years or more, and upon this foundation had assembled features, some of which were his own ideas and were distinctly ingenious, so that a perfect structure was obtained. The patent was granted on August 12th, 1851, and his handiwork so favourably impressed a few friends that they advanced him two or three hundred pounds on loan, to enable him to commence manufacture.

There was one feature of the Singer machine which caught the general fancy, so far as it was possible so to do in an age when the American market was flooded with spurious sewing machine claims and "wild-cat" schemes for deluding the public. With this machine, although hand-power could be used, it was not necessary. It could be operated by the foot, thus leaving the two hands free to attend to the fabric and actual sewing operations. The means to this end were decidedly novel. The sewing machine was packed in a special box which was designed to serve as a table or cabinet. Within the box, which was stood on one of its sides, was a foot-plate made of wood, hinged at one end and free to move up and down. From the free end of this plate extended a rod or rough wooden pitman, which was connected to the balance-wheel or hand-wheel, which, when revolved, transmitted the power to the mechanism through gearing. This foot action could be brought into use or disconnected in one or two seconds, as desired. Strange to say, although the introduction of the treadle motion to the sewing machine certainly constituted a distinctive characteristic, and is universally used to-day, Singer neglected to cover this action by patent.

Singer thought that the public would welcome his idea with open arms. He cherished the opinion that a perfect, reliable, and simple sewing machine,





HIGHER DEVELOPMENTS OF THE SEWING MACHINE

A Singer machine which is used for closing up bags—that may contain bird sand, for instance—when they are full.

Singer machines for over-edging lace curtains. It trims, scallops, and over-edges lace curtains at one operation.

obtainable at a low price, would arouse the enthusiasm of the housewife and the manufacturer alike. But he was speedily disillusioned. It was regarded with the utmost suspicion, the public having paid dearly for their credulity by acquiring machines which were worthless and had to be thrown away. Moreover, the outcome of Howe's litigation, whereby every user was mulcted in a penalty by having to pay a royalty to the man whom the law had declared to be the inventor, had precipitated widespread disgust. Singer strove hard to overcome this hostility. He even shouldered a machine himself and went round from door to door among the seamstresses and tailoresses. When they received him with ridicule and point-blank declined to listen for a moment to his pleadings for a chance to prove his statements, he unhesitatingly withdrew his machine from its case, connected it up, and on the doorstep would prove there and then what it could and would do. In this manner he literally forced his invention into homes and workshops.

It was a desperate, uphill struggle, but determination won in the end. The machines began to arouse interest and to be discussed in a friendly manner. The sceptical came to his humble home which served as a workshop, saw, and were convinced so effectively as to place orders with him. When he suggested to another inventor, Blodgett by name, that he intended to manufacture sewing machines, Blodgett, who had striven to introduce a sewing machine of his own design and had encountered heartrending failure, advised Singer strenuously to abandon such a mad project, and instead, to dispose of the rights to make the machine in certain territories for a round figure.

"Sewing machines will never come into use, Singer. I'm a tailor, and know more about the situation than you do. Sell territorial rights, make as much money as you can, and clear out of the market as quickly as possible."

Singer rejected the advice and continued on the path he had carved out for himself. His tiny works were becoming taxed to their utmost, and the outlook appeared decidedly cheerful. Then came a dark cloud which threatened to shatter his castles in the air. One night Elias Howe paid him a visit and in threatening tones demanded the sum of £5,000 as compensation for the infringement of his patent rights. Singer, who had started his idea on a modest borrowed £8, and even now was struggling hard, was not to be intimidated. In the first place, he had not £5,000 by him; in the second, he held his own opinion concerning the value of Howe's patent.

Howe, unable to secure the satisfaction he demanded, at once sought the assistance of the courts. Singer was overwhelmed with litigation and was faced with extinction. But Singer was not a man to be cast down very readily. He fought Howe tooth and nail, step by step, and the plucky fight against overwhelming odds, in which the best legal talent was engaged, brought an unexpected development. Singer's leading counsel, a Mr. Clark, was attracted to the determined mechanic and to his handiwork, as well as to his grand idea of turning out the machine at such a low price as to bring it within the reach of even the poorest needleworker. Clark fought the battle doggedly, but Howe's position proved unassailable. The courts declared Singer's machine to be an infringement of Howe's invention inasmuch as it gave the continuous lock-stitch, which had to be formed after the lines laid down by Howe. Consequently Singer, in common with every other sewing machine inventor, had to pay tribute to Howe until the master patent expired in 1867.

Singer was bitterly disappointed at the decision against him, as thereby all his ambitions appeared to be dashed to the ground. The cheap machine was rendered impossible. But practical and financial assistance came from an unexpected quarter. Clark, his leading counsel in the case, came to him and suggested that if Singer would allot him a half-share in the invention, then he would push it for all it was worth, and convert it into a profitable enterprise. Seeing that Clark, by virtue of his eminent position, was likely to fulfil his promises, an arrangement was drawn up. The moment the partnership was signed the future of the Singer sewing machine was assured.

Clark was a man of energy, action, imagination, and unbounded enthusiasm. He approved of Singer's great idea of introducing the sewing machine into every home. It was merely a question of organisation and adequate financial resources, and the firm of I. M. Singer & Co. was founded. Clark had the capacity of judging men, and he selected his staff with care, securing the right men for the right positions. In 1856 Singer's original plan came into commercial application. He had cherished the idea of selling the machines direct to the public and without any intermediate agency whatever. Also he urged that the system of sale should be such as to enable the poorest individual worker to be in a position to compete with the wealthy manufacturer. He outlined his plan, which was to sell on the instalment system, or, as it is more generally known now, by hire-purchase. As a matter of fact, Singer was one of the first pioneers, if not the actual pioneer, of this method of transacting business.

From the very beginning the idea caught the popular fancy. It appealed to the humbler seamstress because with a machine she was able to increase her meagre earnings, while the instalment for the machine was so small as to be negligible. The machine paid for itself easily. The housewife regarded the issue in a similar light, while the small manufacturer, whose bank balance was not adequate to enable him to lay out a large sum of money for the equipment of his factory, also received the proposal with open arms. Branch offices were established; first, in all the foremost cities of the United States; then the outlying towns carried their representatives; and finally, even the small villages were brought into the organisation. It was quite a new way of conducting business, and the customers appreciated the system of direct selling, because they were relieved of the anxiety and delay when accessories or new parts were required, these being readily obtainable through the agencies. Moreover, the machine was being perfected from day to day, and when a decisive improvement needed a new model, the advantageous terms which were offered to existing customers to acquire the latest word in sewing machines met with an instantaneous response.

The system proved so remarkably successful that by 1863, seven years after the inauguration of the scheme, the sales had risen to 21,000 machines annually. The enterprise had reached such a healthy, prosperous stage that the existing company was inadequate to cope with the business in hand. Thereupon a new company was formed under the title of "The Singer Manufacturing Company," under which style it is known to this day. The two original partners having placed the undertaking upon a solid foundation, and it being merely a matter of routine for future working, they retired from all active participation therein, although they still held a large interest in the concern, from which they ultimately accumulated huge fortunes.

The new company went ahead with all the vigour of its predecessor. In 1867 the annual sales had risen to 42,000 machines, while during the next four years the output increased by such leaps and bounds as to reach the figure of 181,600 machines for 1871. The new company extended its sphere of operations, introducing the machine to all the countries of the world, and in every instance the successful line of conducting business was brought into effect. The Chinaman residing on the borders of Tibet, the peasant in the Caucasus, the lonely shack-dweller upon the borders of the Arctic circle, is able to acquire the sewing machine on the hire-purchase system with the facility of the housewife residing in London, Paris, or any other large city or town. The Singer Sewing Machine Company recognises no distinction between nations, and no geographical boundaries. It pushes its way to wherever there is an opening for its activities. Each country carries its distinctive organisation, formulated according to the laws of the country in which it is engaged in business, and when exigencies so compel it, establishes its local factory.

Upon the lapse of Howe's extended patent the business advanced even more rapidly. The long period during which tribute had to be paid in the form of royalties came to an end, and the public immediately received the benefit of the new order of things. The equivalent of the royalty was instantly knocked off the selling price of the article, notwithstanding the powerful position which the organisation had acquired at this time. In fact, upon the expiration of the master patent, additional energy appears to have become infused into the firm, because by 1878 the company was making and selling over 350,000 machines per year, which total was lifted to 800,000 machines per annum in 1896. Even the latter figure, although it appears to be huge compared with the sales in 1863, fades into insignificance besides the annual sales to-day, which exceed 2,000,000 machines per year.

As may be supposed, enormous factories have been created to yield such a huge output. The parent factory is at Elizabethport, New Jersey, U.S.A., but it has been exceeded in dimensions by one of its family. The Singer factory at Clydebank, Scotland, ranks as the largest establishment in the world devoted to the manufacture of sewing machines. In normal times its pay-roll comprises 14,000 employees. The company owns vast tracts of forests in America, whence all the timber required for Singer cabinet work is derived. Its consumption of steel and other metal reaches an enormous figure during the course of the year. The company maintains over 8,000 branches scattered throughout the world, while its employees, engaged in some capacity or another, form a vast army of men and women.

But from the original Singer of 1851 to that of the present day is a far cry. Its sphere of use has been steadily and persistently extended until at the present time it is applicable to virtually every purpose wherein one piece of material has to be attached to another. The machines will cope with leather two inches in thickness as readily as two pieces of muslin. Nor are they confined to what might be termed straight sewing duties. They will make button-holes and even sew on the buttons, though of course the design of the machine varies in detail according to the particular character of the duty which has to be fulfilled. It is even possible to equip the machine with more than one needle, the maximum in this direction being twelve needles set side by side to make an equal number of parallel rows of stitches, and each drawing its supply of thread from its own reel, so that various coloured threads may be used at one and the same time. The total capacity of this machine is 9,000 stitches per minute. Think of it—150 perfect lock-stitches every second!

The machine has also displaced hand-labour in another field—fancy work. Indeed, its possibilities in this direction appear to be illimitable. Some of the achievements executed by the sewing machine in this realm at first sight appear to be impossible, and certainly may be classed as *pièces de résistance* from the artistic and mechanical sewing points of view.

Although Singer introduced the treadle in his very first machine, thereby releasing the hands for attention to the work, many ingenious efforts have been made even to supersede the foot action. Of course, in large factories the machines are driven by power, but considerable ingenuity appears to have been displayed to adapt a power-drive to the single domestic appliance. During the first twenty years of the sewing machine's history, after its introduction to commerce, a round seventy-five patents were granted for motors to fulfil this task. In the greater number dependence was placed upon the action of coiled steel springs demanding periodical winding in the manner of a clock. Needless to say, these fantastic conceptions failed to realise any profitable results for their ingenious creators. But the coming of electricity and its universal application brought about a far-reaching change. To-day it is not difficult to render the home sewing machine independent of both hand- and foot-labour, provided electric current is available within the house. A small motor, developing about $\frac{1}{8}$ horse-power, is mounted beneath the table, fed from an overhanging electric lamp or wall plug, and controlled by a switch, and the cost of operation in this manner is about the same as that of running a 16 candle-power electric lamp. The advantage of the machine driven in this manner is a higher sewing speed, this averaging about 800 stitches per minute as compared with 200 to 400 stitches per minute with the foot. The stitching speed is controlled in an ingenious manner, merely depending upon the pressure exerted upon the treadle. The lighter the pressure the slower the speed, and vice versa.

Printed by Cassell & Company, Limited, La Belle Sauvage, London, E.C.
F.30.619