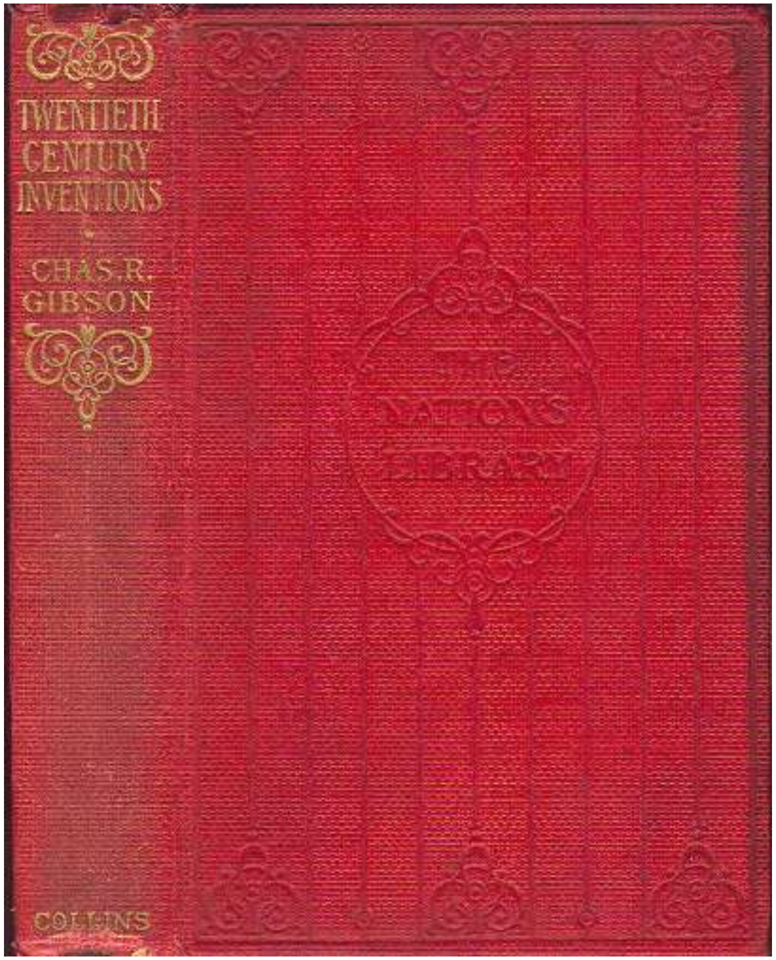

20TH CENTURY INVENTIONS

By

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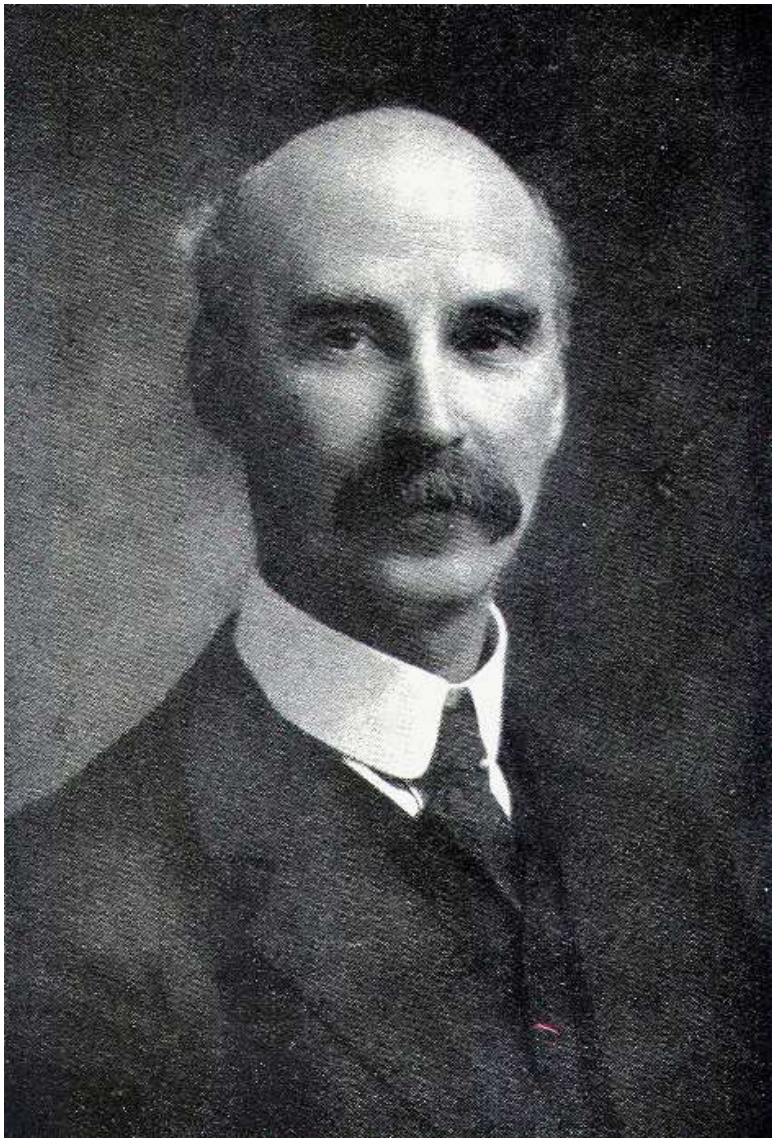

CHARLES GIBSON.

INTRODUCTION

The object of this volume is to present to the general reader a clear idea of some of the most interesting inventions of the twentieth century. Although we have not travelled very far into the present century, there has been a host of inventors at work, with varying degrees of success or failure. Since the beginning of 1901, no less than 199,000 patents have been sealed, while the total number of applications lodged has been between 300,000 and 400,000. Hence it goes without saying that the present volume does not include all the inventions of the twentieth century: a mere list of the titles of all these would occupy twenty volumes of this series.

In selecting the sixty inventions with which this volume deals, the guiding principle has been the degree of ingenuity embodied in the invention. We are not concerned whether this or that particular invention is superior for some practical purpose, but rather which is the most ingenious.

The description of what a certain piece of mechanism does is of some interest, but a description of how the desired operations are achieved is of very much greater interest, and so the latter plan has been adopted in the present volume. It will be understood that to describe any complicated invention in non-technical words is necessarily more roundabout than to use technical words, each of which may stand for what must be expressed otherwise in a phrase, a sentence, or even a number of sentences. In order to make the descriptions entirely non-technical, it has been necessary to give the reader a mental picture of each invention. There has been no attempt to treat the subject historically, except where the evolutionary steps have seemed to be necessary towards a complete understanding of the invention.

Charles R. Gibson.

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TELEGRAPHING PHOTOGRAPHS

Of the recent inventions in connection with electrical transmission there is no doubt that the telegraphing of photographs is of most general interest. There are now several methods of transmitting photographs electrically, but the most outstanding and the most interesting from the invention point of view is that devised in 1904 by Professor Arthur Korn, then of Munich, now of Berlin.

The general idea is, of course, to cause a photograph to control an electric current, which when transmitted to a distance may rebuild a duplicate of the controlling photograph.

It had been known for a generation that the non-metallic element selenium, when in a two extremes of no light (opaqueness) and full light (transparency) there would be in every photograph an endless variety of light and shade.

In order to bring each part of the photograph beneath the pencil of light, the cylinder is caused to rotate and to move longitudinally, so that the point of light traces a continuous spiral around the cylindrical photograph from end to end. We have the same relationship between a phonograph cylinder and its stylus.

As the pencil of light falls upon the different parts of the photograph in turn, there will be an endless variety in the intensity of the beam of light issuing from the end of the cylinder and falling upon the selenium cell, and there will be a corresponding variation in the electric current passing through the cell. We might picture this ever-varying current passing out on to the long-distance line, but the action of the selenium cell is not quick enough. This led Korn to invent a compensating arrangement, by which he gets rid of this inertia trouble.

The compensation is brought about by using two selenium cells on opposite sides of crystalline condition, had its electrical resistance altered very materially by light falling upon it. Selenium cells are made so that in the dark they prevent the passage of an electric current through them, but when exposed to light they have their electrical resistance so greatly reduced that an electric current passes freely. Between these two extremes of no light and full light, the selenium cell acts according to the intensity of the light which impinges upon it. Professor Korn has made use of such selenium cells in his invention.

Having made a flexible transparent positive of the photograph, the inventor wrapped this around a cylinder of glass. He then caused the light from a Nernst lamp to pass through lenses, which caused a concentrated beam or fine pencil of light to fall upon the transparent photograph. If this spot of light fell upon an opaque part of the photograph, no light would enter the cylinder, but if it fell upon a transparent part the light would pass into the glass cylinder and there fall upon a right-angled prism, which would reflect it out at the end of the cylinder to fall upon a selenium cell. Between these a Wheatstone bridge, and dividing the battery into two parts for the other two sides. Tip first or main selenium cell is so composed that it has small inertia and high resistance. This means that while it will act quickly, it will only let a small amount of electric current pass. The second cell has large inertia but low electrical resistance. The current from the first cell, which is controlled by the photograph as already described, is now shunted across a circuit containing a string galvanometer. In this instrument, there are two fine silver wires carrying a light shutter of aluminum foil, and these are free to move laterally in a strong magnetic field. While no current passes, the little shutter blocks the way of a pencil of light from a second Nernst lamp, and prevents it reaching the second selenium cell. When the wires and shutter are deflected by the current from the first selenium cell, they allow the beam of light to pass, and it is reflected by a prism, which causes it to fall upon the second cell. The greater the current, the greater the deflection of the silver wires, and the greater the action on the second selenium cell.

It will be observed that both cells are working in unison under the control of the photograph, and these constitute two sides of a Wheatstone bridge, which provides a much more sensitive apparatus. Instead of the electric current rising gradually and falling slowly, when the light is suddenly admitted and withdrawn, it rises very rapidly and falls to zero almost immediately.

This controlled current is sent on to the long-distance line, and at the receiving end the current actuates a string galvanometer similar to that used as a compensator in the transmitter. In the receiver, the little aluminum-foil shutter, under the influence of the incoming current, controls a pencil of light from a Nernst lamp. We might picture this ever-varying pencil of light falling upon a sensitive film, wrapped around a rotating cylinder, and thus building up a duplicate of the transmitting photograph. But this first galvanometer is used as a relay to control a local battery current. Instead of falling upon the photographic film the light falls upon a selenium cell, which controls the local battery and operates a second string galvanometer. The aluminum-foil shutter of this instrument controls the light from a second Nernst lamp, and this pencil of light is focused upon a small aperture in a screen which protects the photographic film. When at rest, the shadow of the little aluminum-foil shutter falls upon this aperture, and no light can reach the sensitized film, but when the galvanometer is actuated the shutter is deflected and allows light to pass; the greater the incoming current the greater the intensity of the light passing through the aperture.

It will be obvious that if the rate of longitudinal movement given to the rotating cylinder be great, the resulting picture at the receiving end will be made up of distinct lines, for the pencil of light will trace a comparatively coarse spiral around the receiving drum. On the other hand, if the longitudinal movement be very slow the lines may be made practically to touch one another, and produce a solid effect. No matter how solid the picture may be made to appear, it will in reality be built up of lines varying in thickness according to the movements of the controlling shutter in the string galvanometer. Of course, when the film is taken from the drum and the developed photograph laid flat, there is no appearance of a spiral, but what appears to be a series of fine parallel lines.

One of the many difficulties which Professor horn had to overcome was the fact that the movements of the string galvanometer would not be exactly proportional to the strength of the electric current received. Suppose the galvanometer to be so adjusted that the maximum current which could arrive would deflect the shutter so as to completely uncover the aperture, and allow the maximum of light to pass through the lens to the sensitized film. With half the maximum current, the lens would not be exactly half uncovered, and so on. One method by which the inventor overcame this difficulty was to make the aperture of some form that would admit an increasingly greater proportion of light the further it was uncovered. It was found that a right-angled triangle was the best form of opening. Even this was imperfect, so a piece of toned film, dark at one part and shaded off to transparency, was placed behind the triangular aperture. This was so placed that the point of the triangle which is first uncovered is protected by the dark part of this film, while the shaded part admits an increasingly greater amount of light as the shutter opens wider. By means of this screen placed in front of the lens, the light is made proportional to the electric current received, and also to correspond with the intensity of light at the transmitting station.

At each station there is a transmitter and a receiver placed side by side, but it is found unnecessary to duplicate the string galvanometer arrangement. The one set of galvanometers will serve both for transmitting and receiving.

Another difficulty which the inventor had to overcome was to ensure that the receiving cylinder carrying the sensitized photographic film would keep in exact step with the transmitting cylinder upon which the sending photograph was fixed. Unless there is complete synchrony between these two far-distant cylinders, the result cannot be of any service; the parallel lines would not be placed in proper relationship to one another. A most ingenious method is adopted, whereby the cylinders are synchronized at the end of every revolution. Each cylinder is driven by a similar electric motor, but the motor of the receiving cylinder is set to run about one percent faster than the motor of the distant transmitting cylinder. This is done so that the receiving cylinder will come to the end of its revolution very slightly in advance of the transmitting cylinder. As soon as the receiving cylinder has completed its revolution it is automatically stopped by a projection on a disc on the cylinder shaft being caught by a pawl. The motor still runs on at even pace, but the cylinder, being driven by a friction clutch, is held stationary so long as this pawl remains engaged with the disc on the cylinder shaft. But as soon as the distant transmitting cylinder (which is one percent behind the receiving cylinder) has completed its revolution, it makes an electrical contact, which sends a current along the line wire to an electro-magnet which immediately releases the pawl and allows the receiving cylinder to set off on another complete revolution. And so on the two cylinders go, the receiving one always trying to get in advance, but being held up at the end of each revolution long enough to set off again at exactly the same moment as the sending cylinder. In this way the two cylinders rotate in complete synchrony.

It will be observed that the synchronizing impulse is sent over the line wire, and yet it must not enter the sensitive string galvanometer at the receiving station, for if it did so it would damage the instrument. Protection is secured automatically, for when the receiving cylinder is stopped by the pawl, it cuts out the photographic connections so long as the cylinder remains at rest. As soon as the pawl is released these electrical connections are re-established. This momentary halting of the cylinder, with its accompanying withdrawal of the light, is arranged to take place while the join of the photograph is opposite the beam of light, so that there is no interference with the continuity of the lines producing the picture.

The electric motors which drive the cylinders are run at a speed of about 3000 revolutions per minute, and this high speed is reduced by gearing so that the cylinders revolve thirty times per minute. Before commencing a transmission the operator sets the speed, which is controlled by regulating a resistance which is placed in series with the field magnets of the motor. The operator starts the motor and watches a speed indicator or 1frequency meter1 connected to the motor. This indicator is very ingenious. It consists of an electro-magnet with a laminated core, so that it can respond quickly to changes of magnetism. It is supplied with an alternating electric current from collecting rings fixed on the armature of the motor. The magnetism of the laminated core of the electro-magnet will therefore change its polarity at each half-revolution of the motor, which will be 6000 times per minute. A piece of steel spring, fixed at one end and free to vibrate at the other, is placed over the pole of this electro-magnet, and the steel tongue is tuned to vibrate freely 6000 times per minute (100 times per second). When the magnet is receiving too many or too few impulses from the rotating motor, the vibrating tongue will not respond, but as soon as the speed is 3000 revolutions (giving 6000 impulses) the steel tongue will sing out a clear musical note.

In order that the operator may have a little latitude in the tuning of his motor, the indicator is supplied with other two vibrating steel tongues. One of these is set to vibrate at 99 vibrations per second, and this will be set in motion when the motor is running at 2970 revolutions per minute (99 x 60 ÷ 2). The other vibrator responds to 101 vibrations per second, and will be actuated by the electro-magnet when the motor is running at 8030 revolutions per minute (101 x 60 ÷ 2).

While the operators are adjusting the speed of the motors by means of these frequency meters, they use a telephone on the line wire, and mutually adjust their motors to whichever frequency they find convenient. The telephone enables them also to adjust the string galvanometers and to arrange the whole apparatus generally.

As already stated, this system of telegraphing photographs was invented by Professor Korn in 1904. It was used between Paris and London, for the *Daily Mirror*, from the autumn of 1907 till the summer of 1909, when a different system was installed. This is known as Korn's telautographic system, and one form of it is known as Thorne Baker's telectrographic process. While Professor Korn has worked out this more mechanical system, he has not neglected his selenium process, and he is hopeful of applying it to long-distance submarine cables. He hopes to be the first to telegraph a photograph from Europe to America, and he is aiming at doing so in time for the San Francisco Exhibition (1915).

The telautographic system is not of the same scientific interest as the selenium process, but it is of considerable practical interest. The operation of light plays no part in the telautographic transmission. The photograph which is to be transmitted is printed as a half-tone picture upon a sheet of lead-foil. The printing material is not ink but fish-glue, which is a non-conductor of electricity. In the half-tone reproduction the photograph is broken up into lines, and is wrapped around a metal cylinder, while the point of a metal stylus passes over the revolving picture, just as the spot of light did in the selenium process. An electric current passes through the stylus and the lead-foil to the metal cylinder and thence to the line wire, by which it reaches the distant station. When any part of the fish-glue printing comes beneath the stylus, the electric current cannot pass to the line wire. While a constant electric current is supplied to the stylus, it is an interrupted current which passes out to the distant station. These interruptions in the electric current will correspond with the number and width of the printed lines over which the metal stylus passes.

At the receiving station this interrupted electric current passes to a metal stylus and metal cylinder similar to that already described; but in this case it is a chemically-prepared paper which intervenes between the stylus and the metal cylinder. This paper is absorbent, and the incoming electric current can pass through it. The current produces an electrolytic effect which darkens the paper. If a constant electric current were received, there would be a continuous darkening of the paper, but the lines of fish-glue on the transmitting cylinder interrupt the constant current, so that during these interruptions the receiving paper remains white. In this way a black-and-white duplicate of the fish-glue picture is reproduced at the receiving station. The results are wonderfully good, and this simplified apparatus is at work between Paris and Berlin, and Monte Carlo and Paris, while similar apparatus is used between Paris and London, and London and Manchester. The author has received from Professor Korn a telautographic photograph which was transmitted from Monte Carlo to Paris, a distance of 750 miles, and which took only twelve minutes in transmission.

It is even possible to send a photograph by wireless telegraphy, although this has been done only experimentally at present. In the telautographic system, just described, the electric current under the control of the photograph may operate a wireless transmitter instead of passing out on to the line wire.

At the transmitting station the interrupted current actuates an electro-magnet which attracts a soft iron diaphragm at each impulse. When this diaphragm is attracted and let go, it closes and opens the primary circuit of a transformer, causing sparks to take place at the air-gap in the secondary circuit. This secondary circuit is connected to an aerial and to the earth as in ordinary wireless telegraphy. At each make and break made by the diaphragm, electric impulses are set up in the aerial, and these send out electromagnetic waves through the ether of space to the distant station. These waves are entrapped by an antenna as in ordinary wireless work, and the electric impulses produced by these waves reaching this second aerial, are conducted to a detector, which acts as a very sensitive relay, permitting a local current to pass at each impulse received. This local current passes through the stylus, prepared paper, and the metal cylinder, and the picture is built up in the manner already described. But as time is required for the makes and breaks made by the detector, it is only possible to transmit very simple sketches or diagrams at present. However, the wireless transmission of a plan, showing the disposition of an army, might be very useful in time of war.

Having no line wire, the synchronizing of the cylinders is more difficult in wireless transmission. One method of keeping the revolving cylinders in step with each other is to set them both to travel slightly faster than required. At the end of each revolution they are caught by a pawl and held till the time set aside for each revolution has passed. The release is brought about by a chronometer controlling each cylinder. If the two chronometers keep in exact step with one another then the two cylinders will be perfectly synchronized.

Another method is to adopt a plan similar to that already described in connection with the line system. The receiving cylinder being in advance, throws itself out of action at the end of each revolution, switching off the detector from the photographic apparatus. At the same moment the coherer has switched itself on to a relay circuit, so arranged that when the distant transmitting cylinder sends out the next wireless impulse on the completion of one complete revolution, the relay in the receiver releases that cylinder, and the two cylinders set off in unison once more. This method can be used only over short distances, but the chronometer method gives very fair results and is independent of the distance. The speed of the rotating cylinders is considerably lower than with transmission over wires.

Professor Korn has made some wireless experiments by means of an improved system. In these he used the telautographic method of transmission, but with a selenium cell and string galvanometer in the receiver. The receiving circuit in which the wireless detector is placed is tuned to the distant transmitting circuit, and a constant stream of ether impulses is maintained, to be broken only by the transmitting stylus coming on to a conducting part of the metal-foil. This short-circuits part of the inductance coil and thus alters the rate of the ether impulses, putting them out of tune with the receiver. Therefore the detector in the distant receiving station is actuated only so long as the transmitting stylus is passing over the fish-glue parts of the sending photograph.

The string galvanometer, which is actuated by the detector, is somewhat simpler than that used in transmission with wires. In wireless work the galvanometer consists of a single wire or fine metal thread through which the currents are passed. This conductor will, of course, possess a magnetic field so long as any current passes through it. It will therefore be deflected by an electro-magnet between the poles of which it is stretched. The light from a Nernst lamp is concentrated upon this wire, and an image of the wire is projected on the slit of a tube leading into the box in which the sensitized film is rotated. When the galvanometer is traversed by a current, the wire is deflected and the shadow moves away from the slit, and light reaches the photographic film.

Although wireless photo-telegraphy is only in an experimental stage, there is reason to hope that those experiments will lead on to some practical system which should be of great service.

Page-Printing Telegraph

In 1905, Donald Murray, an Australian journalist, read a paper before the Institution of Electrical Engineers (London), on the subject of setting type by telegraph. About five years earlier he had arrived in New York with a new invention which was to print telegrams in page form, and was to be operated over a single telegraph line.

The idea itself was not new, there having been patented no less than 150 such inventions during the nineteenth century, but Murray's invention was on an entirely different principle. He was not going to attempt to control a complex typewriting machine by means of a single telegraph line; his idea, although not developed fully at that time, was to prepare a perforated paper-ribbon, such as is done for the Wheatstone automatic transmitter. He then proposed to use this paper-ribbon to control an electric current passing out to the telegraph line, and at the receiving station an instrument was to prepare a duplicate ribbon. Then this telegraphically-prepared ribbon was to be run through an automatic typewriting machine, which would print the telegram in page form.

But the first Murray printing machine was primitive, and was described in New York as "a sort of cross between a sewing-machine and a barrel-organ," the operator having to turn a handle to drive the machine. It received nicknames such as "Murray's coffee-mill," the "Australian sausage-machine," and, perhaps more reasonably, the "Baby," indicating that the apparatus required a good deal of nursing.

Printing telegraphs had been used on the Continent for a generation, but these printed the message on a long tape, and their speed was limited to hand signalling, whereas the ?Murray telegraph was to print in page form at a very high speed.

The invention in its practical form consists of four separate machines. First, there must be a perforator for punching the symbols on the paper-ribbon. Then a transmitter for signalling to the distant station. Thirdly, a recorder for receiving the transmitted signals, and preparing a duplicate of the transmitting ribbon. And, finally, a typewriting machine which can be controlled by the perforated ribbon.

The 'perforator' has a typewriter key-board, which is manipulated in the usual manner, but instead of printing Roman characters on a sheet of paper, it punches holes in a paper-ribbon. Just as in the case of the Morse Telegraph, definite combinations of dots and dashes represent all the letters of the alphabet, so in the Murray Telegraph, definite combinations of perforations make up the whole alphabet. There are five punches in the perforator, and when the letter 'A' key is depressed on the keyboard, the first two punches act simultaneously. When the key 'E' is depressed, the first punch only is called into play, while the letter 'T' operates only the fifth punch, and so on until the whole alphabet is completed by different combinations of these five punches. There is a central row of feed-holes, which is punched beforehand. This is done at a great speed by pulling the ribbon through between a punch-wheel and a die-wheel. If desired, it could be done automatically on a large scale, as is the case in perforating sheets of postage stamps.

It will be understood that the speed of operation of the perforator does not necessarily determine the speed at which the messages are to travel over the telegraph line. We know that in the case of the Wheatstone automatic sender, the speed of preparing the perforated ribbon is slow, the punching of each individual signal having to be controlled separately, four movements of the operator's hand being required to signal many of the letters. But the speed of the punching machine bears no relationship to the speed at which the prepared tape may be rushed through the automatic transmitter, while the automatic recorder acts in sympathy. The Murray perforator has the advantage of only one movement of the operator's hand to punch the complete signals forming each letter.

In ordinary typewriting the typist has to go carefully to avoid mistakes, as corrections disfigure the production. But in operating the typewriter keyboard of the Murray perforator the operator can use more freedom. If a mistake is made it does not require to appear in the printed telegram. This advantage belongs in some measure also to the Wheatstone automatic transmitter, in which a mistaken perforation may be cancelled by punching a number of 'A' s,' and then proceeding with the correct perforation. The distant recorder will duplicate these obliterating signals, in the form of a series of dots on the receiving ribbon, but the subscriber knows to take no notice of them in writing out the message. In the Murray telegraph, the obliterating holes appear in the duplicate ribbon produced by the receiving instrument; but when this is run through the printer, that machine stops momentarily till the obliterating holes have passed. Not only does the machine cease printing, but it does not feed the telegraph-form forward until the printing recommences. In this way no trace of the correction appears in the finished telegram.

The perforator is operated electrically, and when a letter-key is depressed it switches on the current to an electro-magnet, which operates the punches on the front stroke of its armature, and on its back stroke feeds the paper-ribbon forward one letter-space. It will be obvious that the operation of the perforator is not dependent upon any knowledge of the signals on the part of the operator; the manipulation is the same as in an ordinary typewriter.

The prepared ribbon is then used to control the electric current passing out to the distant station. As already stated, the object of the Murray single-line transmitter is to reproduce, at the receiving station, a duplicate of the perforated ribbon. There are two well-known methods of automatic transmission from a perforated ribbon. In the one system the electrical contact is made directly through the holes in the ribbon. So long as the solid ribbon intervenes between the rolling contacts no current can pass, but as soon as a hole comes along the current gets through from roller to roller. The other system is on the principle of the Jacquard machine, which is used to control weaving looms; the perforations operate a number of small rods or 'needles.' In the telegraph transmitter it is the corresponding 'needles' which operate the electrical contacts. This indirect method of transmission has been found to be the most reliable.

The electrical current, which the perforations are to control, is made up of alternate positive and negative currents, as is also the case in the Wheatstone transmitter. In the Murray transmitter only one row of punched holes is used, whereas two rows are necessary in the Wheatstone. And, consequently, only one small upright rod for entering the perforations is required in the Murray, in place of two in the Wheatstone. The upper end of the small rod presses gently upwards against the underside of the paper-ribbon, while the lower end of the rod operates a combination of levers which make the desired electrical contacts. The transmitter is driven by a phonic-wheel motor, the electric impulses for which are timed by a vibrating reed or pendulum, the inertia of the phonic-wheel being sufficient to ensure uniform motion. This arrangement is very convenient, as variation of current strength has no effect upon the speed of the motor.

At the receiving station the telegraph current enters a distributing mechanism. The short electric impulses as they arrive are sent alternately to a punching-magnet and a spacing-magnet. When there are no signals arriving, a special device cuts out the spacing-magnet by opening a switch, and so stops the forward motion of the paper-ribbon. But as long as signals are passing, the vibratory action of the spacing-magnet is continuous, and the ribbon is fed forward at a definite rate. As already stated, the punching-magnet works alternately with the spacing-magnet, but only when there is marking current in the telegraph line.

The little punch in the receiving instrument is operated by the movement of the armature of the electro-magnet (punching-magnet). The movements of the armature are in turn under the control of the telegraph current, and that again is controlled by the movements of the small vertical rod, which is controlled by the perforations in the transmitting ribbon. In this manner the little punch in the receiver duplicates the movements of the small rod in the transmitter, the result being an exact duplicate of the perforated paper-ribbon. In the transmitter a perforation moves the rod, and in the receiver the moving punch makes a perforation.

The next step is to translate the perforations into Roman letters, by means of the automatic typewriter. The perforated ribbon passes over a drum, which operates in exactly the same manner as in a Jacquard loom. At each stroke of the machine the perforated ribbon is fed forward one letter-space, and then the drum moves forward against the points of five little rods or 'needles,' and then retires, to repeat the operation after having fed the ribbon along one more letter-space. But for the intervention of the paper-ribbon, the five needles could enter holes in the advancing drum, in which case they would remain inoperative. But whenever a solid piece of the paper comes opposite a needle, that needle is pushed back by the advancing drum; only a perforation in the paper allows the needle to remain as it was. It will be understood that all five needles take part in each stroke of the machine, but only those opposite which there is no perforation make any move. This part of the instrument is called the selector. The five rods are fixed in the ends of five slotted bars or combs, and no perforation means that the corresponding comb is pushed back about one-sixteenth of an inch.

The five combs are thin flat bars of steel, each having a series of slots, which form spaces between a row of square teeth along one side. They are not unlike the wards of a key continued in a long row. The five combs lie in a horizontal position, the one above the other, with their rows of teeth all facing a set of upright levers, which we shall call 'uprights.' Each upright is attached to a spiral spring which tends to pull the upright against the combs. We picture a regiment of fifty-six uprights, and in each comb there is a corresponding row of fifty-six slots or spaces between the teeth or wards. But when the combs are in their position of rest, the fifty-six spaces of one are not opposite the fifty-six spaces of the next one. Indeed, opposite every upright there is at least one tooth blocking the way into the combined terrace of slots. Therefore, when no needle is pushed back, no upright can be pulled into the slot belonging to it. Before any particular upright can be pulled forward by its spring, the five combs must each show a clear space immediately in front of the upright.

In front of one of the uprights we find that the way is clear except that one tooth on the uppermost comb blocks the way. If we slide this comb along one-sixteenth of an inch it moves the obstructing tooth out of the way and the upright falls forward. The comb will slide along in this manner when its needle is pushed back by the solid paper-ribbon on the advancing drum. If a perforation should be opposite that needle the upright will not be released. Opposite another of the uprights there is a clear space excepting in the second comb, so that no perforation opposite the second needle will operate this upright. We see that five of the uprights may be operated in this simple fashion. But another of the uprights has its way blocked by a tooth in each of two combs. In this case the corresponding two needles must be pushed back simultaneously. And so on we may go till we find an upright whose way is blocked by a tooth in each of four combs, which upright will require the corresponding four needles in the selector to be pushed back simultaneously. This movement will be obtained by having only one perforation opposite the needle of the comb whose space is already opposite the upright.

So far we see how each different signal or combination of perforations operates a different upright. When an upright is free to be pulled forward by its spiral spring, its upper end pushes forward a small hooked lever, which is hanging immediately in front of the upright. A metal bar or 'knife' descends at each stroke of the machine and will catch this hooked lever and pull it down. The hooked lever is hanging from one of the keys of the typewriter, so that the key is depressed and a letter printed on the page of paper, which is in position in the typewriter. When the knife rises and frees the engaged hook, the upright would still remain forward, under the tension of its spiral spring. However, at this moment a straight bar moves back against the upright and pushes it back till it is clear of the combs.

This unlocking bar extends along the machine in front of all the uprights, and no matter which upright has been called for by the selector, that upright will be replaced in its normal position as soon as it has completed its task. All the uprights are thus held clear of the combs until the combs are set in position for the succeeding letter.

In this way the whole fifty-six keys of the typewriter may be operated individually, but it must be made possible to change the printer from letters to figures when necessary. This is accomplished by the addition of a sixth comb placed beneath the other five. When this sixth comb is in one position the machine is set to print letters, and when the comb is pushed along one-sixteenth of an inch the machine is then set for printing figures. The movement of this comb is obtained by two cross-bars, one at either end of the comb. The signal for the letter-shift key is the whole of the five holes punched in the paper-ribbon, thus calling for no letter-key. In this case, when none of the needles are pushed back by the perforated ribbon, the right-hand cross-bar is free to move forward into the slots of the combs. In the sixth comb there is a V-shaped slot, with one straight and one inclined face, while on the cross-bar there is a wedge-shaped piece with one inclined face. When the two inclined faces meet one another, the wedge pushes the comb along one-sixteenth of an inch, and the machine is set for printing letters. If it is desired to print figures, the cross-bar at the left-hand side is operated by a particular combination of punched holes (two perforations, one blank, two perforations). This cross-bar operates the sixth comb, just as was done by the other cross-bar, but moving it along in the opposite direction. In this position the machine will print figures.

During the operation of these cross-bars, it will be observed, there are no letter-keys called for. Hence by making a series of repetitions of five holes in the paper-ribbon, the printer will cease to act at each stroke. It is by this means that 'rubbing out' is attained; while the obliterating signals, referred to in an earlier paragraph, are passing through the printer it is quite inactive, and it is quite impossible to tell from the printed telegram whether or not the operator at the transmitting station made any corrections.

TELEVISION

Many inventors have worked at the problem of seeing at a distance by means of electrical transmission. The problem is not solved, but its solution has commenced, and it may be that before the end of the twentieth century television will be a practical success.

We have seen how it is possible to transmit photographs by an electric current, but to transmit instantaneously a visual image is a much more difficult task. We wish to be able to throw the image of a moving person upon a screen which will transmit an electric current along a telegraph wire and reproduce the image at the receiving station.

Ernst Ruhmer, of Berlin, whose photo-grapho-phone is described in the succeeding chapter, gave a demonstration of his television apparatus in 1909. It was merely to show the principle of a much more elaborate system, which was estimated to cost about £50,000. The demonstration apparatus, by reason of its elementary construction, was capable of reproducing only a simple pattern of squares arranged in different combinations.

At the transmitting station an image of the pattern is thrown upon a screen hung upon a wall. The screen is divided into twenty-five square sections, and behind each of these is a highly sensitive selenium cell. At the receiving station there is a screen, divided into a similar number of square sections, each being connected by wire to the corresponding section in the transmitting screen. Each section controls a separate electric current, which is conducted to the corresponding section in the receiver. By a process similar in principle to the well-known mirror-galvanometer, the fluctuations of the current are made visible by a corresponding variation of light upon the receiving section.

Whatever pattern of dark and light squares is projected on the transmitting screen, a duplicate pattern appears simultaneously upon the receiving screen. The relationship of this simple pattern to the desired image of some natural object, may be realised by considering an analogy. In order to explain how photographs are reproduced in books by half-tone process blocks, it is convenient to magnify a small portion of the printed illustration. We see in the magnified part a collection of black dots crowded together in one portion and almost absent from another portion. In the magnified copy they do not form any resemblance to a portion of a photograph, but if viewed from some distance from which the individual dots cannot be seen, the effect is just such as we do see in looking directly at the printed illustrations, in which the individual dots are so small that they cannot be seen. We may take Ruhmer's simple screen as analogous to a greatly magnified portion of his would-be picture. It would require about 10,000 miniature sections to produce a complete television apparatus.

Two French inventors (Fournier and Rignoux) have devised an apparatus in which the transmitting screen is similar to Ruhmer' s, but with a receiving screen embodying totally different principles.

It should be mentioned that although the two transmitting screens are on exactly the same principle, the German and French inventors were working quite independently.

The first proposal by the French inventors happened to have a receiving screen also on somewhat similar lines to Ruhmer's invention. At the receiving station the incoming currents passed through little coils, or miniature galvanometers, which uncovered a corresponding number of little mirrors. The uncovering was in proportion to the amount of current received, which again was dependent upon the amount of light falling upon the controlling section at the transmitting station. At the receiving station, light is thrown upon the collection of mirrors, which reflect the light according to the amount of mirror space exposed. In this way, the receiving screen duplicates the image on the transmitting screen.

If we are to have 10,000 mirrors in either of these systems, it will mean as many individual connecting wires between the transmitting and receiving stations. But the French inventors believe that they have found a means of dispensing with this multiplicity of connecting wires, and it is in this system that they invented a receiver distinctly different from that in Ruhmer's invention.

In the demonstration apparatus they use a simple transmitting screen having only eight sections and eight selenium cells. The electric currents passing through the selenium cells are necessarily very weak, but they operate local relays which control more powerful currents, and it is these which pass out to the telegraph line. The eight different currents, from the eight cells, are to be conducted by a single telegraph wire to the receiving station. Each current is as it were to have the use of the line for a small fraction of a second, one current impulse following at the heels of the current impulse sent by the neighbouring section. The eight wires are connected to eight contact pieces in a circular switch called the collector. A rapidly rotating wheel carries a collecting arm which sweeps over the contacts in quick succession. This collector arm is connected to the telegraph line, and in this way the eight different currents are conveyed separately along the single telegraph line. It is evident that with a very rapid rotation of the collector, the time between the successive impulses from the same selenium cell will be only a very small fraction of a second. It remains to sort out these impulses at the receiving end.

The receiver in this single line system involves a principle which was discovered by Michael Faraday in 1845. Faraday discovered a direct connection between Light and Electricity. He polarized a beam of light by passing it through a Nicol prism (which permits only waves in one plane to pass), and then he passed the polarized beam through some transparent substance placed between the poles of a powerful electro-magnet. When the beam of light emerged from the magnetic field, it had to pass through a second Nicol prism, and thence to a screen upon which it would form a spot of light. This it could do only so long as the second prism was turned in the same position as the first prism. With the magnet disconnected from its source of current, the beam of polarized light was allowed to pass through the two prisms, and then the second prism was rotated about a quarter-turn until the beam could not pass through, and consequently the spot of light disappeared from the screen. If the electric current was then switched on to the magnet, the spot of light reappeared immediately. The cause of this phenomenon does not concern our present object; we have merely to deal with the facts.

In the receiver of this television apparatus, the old experiment of Faraday's is repeated. There is a lamp sending a beam of light through a Nicol prism, then through a tube containing carbon disulphide (a transparent liquid), and finally out through a second Nicol prism. The incoming telegraph line is connected to a coil of wire forming an electro-magnet around the tube. The arrangement of the prisms is such that no light passes until the magnetic field is present. The stronger the magnetic field is the greater will be the amount of light emerging from the second prism. The magnetic field will be dependent upon the amount of current received, and that again will be dependent upon the amount of light falling upon the selenium cells in the transmitting screen.

So far we have an ever-varying beam of light under the successive control of eight different selenium cells, the impulses following one another in very rapid succession. The next problem was to sort out the eight different currents, and piece them together again. But as the variations of the currents have been already translated into variations in the beam of polarized light, it will be more convenient to sort out the different variations of light corresponding to the different selenium cells which are producing them. This is done by allowing the beam of light to fall upon the periphery of a rotating wheel, upon which a series of small mirrors are fixed. There are as many mirrors on this receiving wheel as there are selenium cells in the transmitter. The wheel rotates in synchronism with the collector wheel in the transmitter, so that the beam while momentarily under the control of No. 1 selenium cell falls on No. 1 mirror, and so on. The little mirrors are so placed that each when receiving the beam of light reflects it to a different part of the receiving screen. For instance, in the simple demonstration apparatus, with its transmitting screen of eight sections, the part of the image falling upon the top left-hand corner of the screen will control the beam of light in the receiver at the moment when the beam is being reflected to the top left-hand corner of the receiving screen, and so on.

In this system, there will he still a multiplicity of wires at the transmitting station and a multiplicity of mirrors at the receiving station, if a complete image is to be transmitted. Neither of these conditions are impossible, and things have been very materially simplified by the abolition of the multiplicity of wires connecting the two distant stations together. A single wire is quite capable of carrying the individual impulses from, say, 10,000 separate selenium cells; the frequency of an alternating current may be 100,000 alternations per second.

To form the complete image of a natural object upon the receiving screen, the rotating wheel of mirrors will throw 10,000 patches of light upon the screen. These patches will be spread over the screen, just as the eight patches of the demonstration were. The patches will follow one another in quick succession, but the rapidity must be so great that, with the aid of our persistence of vision, all will stimulate the eye at one time. In the case of the kinematograph our persistence of vision enables us to see the quick succession of pictures on a screen as though there was no break in the continuity of the light.

It will be understood that no complete apparatus has been attempted, doubtless because of the great cost. But these simple demonstrations are of special interest, as they are the commencement of the solution of the problem of transmitting vision to a distance. We have become familiar with the transmission of sound to a distance, which was considered an impossible thing only forty years ago. Indeed, when Lord Kelvin told the members of the British Association about the telephone which he had seen at the Exhibition in Philadelphia (1876), and through which telephone he had heard extracts from New York papers, he said, "With my own ears I heard all this," and he assured them that there was no room for trickery, as it was his own friend Professor Watson, "who, at the other extremity of the line, uttered these words." It is true that the two problems, the reproduction of sound and the reproduction of vision, are not at all comparable, but there seems good hope for the ultimate solution of television.

CHAPTER II

TELEPHONIC INVENTIONS

POULSEN'S TELEGRAPHONE—RUBMER'S PHOTOGRAPHOPHONE—LOUD-SPEAKING TELEPHONE—SUBMARINE TELEPHONECABLES—AUTOMATIC TELEPHONE EXCHANGES.

POULSEN'S TELEGRAPHONE

In the opening years of the present century, the now well-known Danish inventor, Waldemar Poulsen, brought before the public a most ingenious device, which was called sometimes a 'telegraphone,' at other times a 'micro-phonograph,' or a 'telephonograph,' or, again, a 'magnetophonograph.' All these names are descriptive of the apparatus, the function of which is to record and reproduce a spoken message by electrical means.

The earliest form of the instrument was very like an ordinary phonograph in appearance. There was a cylindrical drum of brass about 11 inches in length by 5i inches in diameter. Instead of a wax cylinder there was a spiral of 225 turns of steel piano wire, of a diameter of about one millimetre. Instead of the travelling tympanum and stylus of the phonograph, there was a small electromagnet, which travelled along in contact with the wire.

In the ordinary phonograph, the original sound causes the tympanum to vibrate and its stylus makes corresponding indentations on the revolving surface of wax. In the ordinary telephone we have an electric current under control of a vibrating diaphragm, causing the electro-magnet in the receiver to vary its magnetization, and thus set up vibrations in the diaphragm of the receiver. In the telegraphone, we have a telephone transmitter, the controlled current from which is led to an electro-magnet, but instead of this magnet controlling a vibratory disc, it magnetizes the steel wire on the cylinder, as it passes beneath the poles of the magnet. We may picture spots, as it were, of magnetization being stored along the whole length of the long steel wire.

Again, in the ordinary phonograph, we have the reproduction of the sound produced by the indentations on the wax cylinder reacting upon the stylus and the tympanum, and in this way producing sound vibrations. In the telegraphone, we cause the spots of magnetization to react upon the little electro-magnet by drawing the wire over its poles. The varying magnetic field sets up induced electric currents which control an ordinary telephone receiver, and reproduce the recorded speech. In this early form of telegraphone, the steel wire could contain little more than one hundred words.

In another type of the instrument, Poulsen placed the brass cylinder, with its surrounding spiral of wire, in a vertical position, and within a stirrup-shaped frame. In this instrument, the cylinder and the recording wire remained stationary, while the little electro-magnet was rotated around the cylinder, describing a spiral, so that its travel corresponded exactly with the spiral of the stationary wire.

The reproduction of speech by the telegraphone is much more perfect than is possible with the ordinary phonograph. In the latter the voice vibrations set in motion a diaphragm or tympanum which is not perfectly free, for the stylus which is attached to it rests upon the wax cylinder. There is no such dampening effect in the telegraphone, in which the telephone transmitter has a perfectly free diaphragm.

The layman might suppose that the record on the wax cylinder would be a more permanent record than the variations of magnetization in the steel wire, but it is quite the other way about. The telegraphone records may be reproduced 10,000 times without any decrease in intensity or deformation being noted, and is practically permanent, if so desired. But few records will be required to be permanent, and it will be convenient to use the wire again for further records. It is only the magnetization which we wish to obliterate, and this is accomplished very easily by exposing the wire to a constant magnetic field. The recording magnet may be connected to a battery, or a permanent magnet may be used in its place, and when the wire is passed rapidly between the poles of the magnet all traces of the variations of magnetization disappear.

In another type of the instrument a flat steel band or ribbon is used in place of a wire. This steel ribbon is passed from one reel to another, and on its way it is exposed to the influence of the recording magnet. The steel ribbon measures about 3 millimeters in width, and is 0.05 millimeters in thickness. It may be made any desired length, and a continuous conversation extending over an hour could be recorded on the one ribbon. Of course, a long wire may be used instead of the flat ribbon if desired. The speed of the ribbon or wire is about seven feet per second, or somewhat quicker than the pace of a smart walk.

When the instrument is used for dictation purposes, an obliterating magnet may be placed a few inches from the recording magnet, so that the ribbon or wire passes the obliterating magnet immediately before receiving the recorder. This is very convenient, for if the speaker desires to correct anything he has dictated, he may reverse the travel of the ribbon and obliterate as much as desired, and then once more take up his dictation.

The instrument, when intended for dictation purposes, is mounted in t small case. On the top of this case are two revolving reels carrying the steel ribbon or wire. These reels are driven by a small motor, which is placed within the case. On the outside, and placed centrally between the two revolving reels, is a movable arm fitted with the recording and obliterating magnets. The ribbon or wire passes through sapphire bushings on this central arm, and then passes over the magnets. The case is provided with a switch which serves to change the various circuits of the recording and speaking battery.

When the typist is taking down a letter from this mechanical dictator, she may have occasion to stop the machine, but that there may be no difficulty in picking up the dictation again, the machine, when stopped, reverses automatically and runs back a few feet of ribbon. In this way, the end of the last sentence is repeated before proceeding with the next. The machine not only performs this reversal automatically, but it cuts out the obliterating magnet so that the record will not be destroyed. This arrangement is particularly convenient to the typist, for the machine is at a distance from her, being placed on the dictator's desk, probably in another room. The typist has only the telephone receiver and the starting and stopping switches beside her. She receives a signal when the telegraphone is free to dictate to her. She then has the machine under her own control.

The inventor has provided means of taking a record suitable for transmission by post. The instrument, devised for this purpose, makes the magnetic record on a flat steel disc, both sides of which may be used. Or if preferred, a polished cylinder of magnetically hard steel may be used. Suitably tempered Bohler steel has been found to give the best results. The thin steel discs are more convenient for postage, and run no risk of injury in transit. These discs measure 13 centimeters in diameter, and are 0.5 millimeters in thickness.

The two reels, between which the steel ribbon or wire is stretched, may be placed some distance apart, and in this way it is possible to tap its record by quite a number of separate electro-magnets, and thus reproduce the sound in as many separate telephone circuits. Arranged in this manner it might be used for purposes similar to those for which the electrophone has been used.

The most interesting use to which the telegraphone has been put is to record conversation coming over an ordinary telephone line. By means of a switch the telegraphone may be connected to a telephone line, so that if a subscriber calling up finds that the person to whom he desires to speak is absent, he may leave the verbal message in the telegraphone attached to the distant end of the line, instead of dictating it to a third party who might not understand it.

It is possible to arrange that the telegraphone left alone in an office will accept any conversation sent over the line. In such circumstances it is necessary for the instrument to intimate to the distant subscriber that the principal is not in, but that he expects to be back at, say, four o'clock. This leaves the calling subscriber free to ring up later or to dictate his message to the telegraphone, if that is more convenient. In this case the telegraphone is arranged to operate its own switches by automatic means.

Poulsen has suggested that his telegraphone might act as a telephone relay; but one of the chief requirements of such relays is in connection with submarine telephone cables, and, of course, to be of real service on a long cable it would be necessary to have the relays inserted in the cable, which is impossible. We shall see at a later point in the present chapter how practical relays have been inserted in submarine cables. Meantime it will be of interest to consider a German invention which records and reproduces sound with the aid of photography.

RUHMER'S PHOTOGRAPHOPHONE

The invention of the photographophone is based upon a discovery made in the end of 1900. In December of that year, a demonstration was given by W. Duddell, before the Institute of Electrical Engineers, showing that when the current of an are varied there was a corresponding contraction or expansion of the vapour column between the carbons. Duddell showed that when the variations were sufficiently rapid, not only was sound produced, but by controlling the variations of the are by musical notes, these could be reproduced by the arc. Even speech could be reproduced, although at that time the words were not very clear.

The arrangement of the apparatus was to place upon the lecture table an open are lamp, to which was connected a telephone circuit leading from some other part of the building. At the distant end of the telephone circuit there was an ordinary telephone transmitter connected to a storage battery of two cells. This circuit formed the primary of an induction coil or 'transformer,' the secondary circuit of which contained a condenser and the distant arc lamp. The arc lamp was, of course, energised by the ordinary lighting current from the mains. The variations of the battery current in the primary circuit, due to the influence of the vibrating telephone transmitter, induced variations in the arc.

When a tuning fork was held in front of the distant telephone transmitter, the arc in the lecture-room was heard to sing out the notes very clearly. If a person whistled a tune into the telephone transmitter, the arc gave a very faithful reproduction. A song was reproduced, although the words were not very distinct. This arrangement, which was described as a 'musical arc,' a 'whistling arc,' and more recently as a 'speaking arc,' suggested, to Ernst Ruhmer, of Berlin, in 1901, the idea of his photographophone.

Ruhmer's idea was to photograph the varying light from the speaking arc, and then use the record to reproduce the sound when desired. The making of the record means in reality the taking of a kinematograph picture, not of the arc itself, but of the series of variations of light produced by the arc. The kinematograph film is placed in a light-tight box and is arranged in such a fashion that it can be run from one reel to another at a regular pace by means of a small motor. The rate of travel of the film is about 21 meters per second, which is very much the same rate as that of the wire in the telegraphone. The light of the speaking arc is focused upon the film, which is kept moving within the box. The film is then developed and fixed in the ordinary way, and we have a kinematograph record of the varying amounts of light. These variations may be seen distinctly on the film, forming a series of shaded bands.

In order to reproduce the sound, it is necessary that the photographic film should control a telephone receiver. The connecting link between these two very different things is a selenium cell, such as has been described already in connection with Korn's electrical transmission of photographs. In the photographophone the kinematograph film is interposed between a source of light and a selenium cell, so that a flickering light will fall upon the selenium. The flickerings will, of course, correspond with the variable transparency of the film-record, and as the electrical resistance of the selenium cell will vary in sympathy with the variations of light which fall upon it, the electric current passing through the cell will vary also in the same manner. This variable battery current passes through a pair of telephone receivers placed in circuit with the selenium cell. In this manner the undulations of light produce corresponding undulations of sound.

The distinctness of the reproduced sound is remarkable, and the loudness may be increased by a more powerful source of light to act upon the selenium cell. It is possible to reproduce the sound with a clearness equal to that of ordinary telephone transmission.

The inventor points out that his system of reproducing sound has an ad vantage over other systems, in that he call produce so easily any number of positive copies from his original negative film. A positive or negative film act equally well in the instrument.

Ruhmer suggests that his photographophone might be used in conjunction with the ordinary picture-kinematograp to reproduce actions and sounds simultaneously. For such a purpose he would use a loud-speaking telephone, such as is described below.

LOUD-SPEAKING TELEPHONE

In the end of 1912, a public demonstration of a loud-speaking telephone was given in America. These telephones were fitted up in the large hall at the Boston Electrical Show, and were used to make announcements to the public, and also to distribute phonographic music. One little incident showed a practical reproduction. The difficulty has been that the diaphragm of the transmitter has a certain tone which is fundamental to it, and when the weight of the moving part attached is increased, this fundamental tone is increased also. Indeed, it is necessary to keep the moving mass small to prevent this fundamental tone interfering with the reproduction of the words transmitted. The same difficulty exists in the receiver.

It was found that it would be of very great advantage to use a phosphor-bronze diaphragm in the receiver in place of the usual iron diaphragm. It is obvious that the phosphor-bronze diaphragm cannot be operated directly by the electro-magnet of the receiver. The inventor attached a lever to the diaphragm, as is done in the phonograph between the tympanum and the stylus. The lever, which is attached to the diaphragm of the loud-speaking telephone, has at its free end an iron armature, which is controlled by the electromagnet of the receiver. In the normal condition of the receiver the diaphragm is free from all tension.

Our present purpose is not concerned with the future of loud-speaking telephones, but use of the invention. A child having been separated from its parents in the crowd, was taken to a position of safety, and an announcement of this fact was made immediately throughout the great building, so that no time was lost in bringing the parents and the child together again. It would be most convenient to be able to give instructions to a huge crowd, and there would seem to be quite a wide field of usefulness in enabling a speaker to address an immense audience.

In the Boston demonstration, there were ninety loud-speaking telephones placed throughout the great building, and these were all operated by one telephone transmitter placed in a sound-proof glass-enclosed cabinet, which for demonstration purposes was in the basement of the Grand Hall.

The problem of loud-speaking telephones is to obtain sufficient volume of sound, without detracting from the clearness. In earlier inventions it was usually the case that a really loud-speaking telephone was obtained at the expense of the clearness of articulation, or, on the other hand, that the volume of sound was sacrificed in order to have clear one wonders if it may be that some day our great men will address audiences of a hundred thousand people gathered together in one place.

SUBMARINE TELEPHONE CABLES

As already mentioned, the Danish inventor, Valdemar Poulsen, suggested that his telegraphone might be used as a telephone relay. The most urgent requirement for a telephone relay, however, is in a submarine telephone cable, which debars the use of anything mechanical.

As submarine telegraph cables were in use at the time of the invention of the telephone, it was natural to try to speak from Europe to America. But when telephone instruments were attached to the two ends of a trans-Atlantic cable, it was found quite impossible to transmit speech. The trouble was that the electrostatic capacity of the cable, whether it be buried in the sea or in the ground, acts as a leyden jar. The capacity of every ten yards of the cable is about equivalent to the capacity of an ordinary leyden jar, so that the capacity of an Atlantic cable will not be far short of half a million leyden jars. This means that the telephone current had to charge the equivalent of these before it could operate an instrument at the distant receiving station.

Not only does the electrostatic capacity of the cable cause a decrease in the amplitude of the current vibrations, but with the telephone it affects the higher-pitch notes more than the lower ones, causing an inequality in the waveform of the current. The higher-pitch notes are not retarded so much as the lower ones, and this adds to the confusion. Indeed, it was found impossible to carry on conversation through more than twenty miles of submarine cable.

In 1900, Professor Pupin, in the United States, showed that speech was greatly improved by the introduction of coils of wire at intervals in the cable. This invention was founded upon the earlier scientific work of Oliver Heaviside, who showed that if the inductance of a conductor were increased, its capacity could be neutralised.

The term 'inductance' may be defined as the property of a circuit by virtue of which the passage of an electric current, in producing a magnetic field, is necessarily accompanied by an absorption of electric energy. This property makes it more difficult to start or stop a current in the circuit. Electrical inductance is analogous to inertia in ordinary matter, and this might seem to mean that the less inductance the better for the telephone circuit, but it is not so. Heaviside showed that telephone cables wanted greater inductance to neutralise the capacity effect. If we think of capacity as being analogous to a vacuum into which electricity will rush, we can see that inductance will hinder this onrush and neutralise it.

No attempts were made to put these ideas into practice, until Pupin had published his experiments with what he called 'loading coils.' The inductance of a circuit is greatly increased by winding the wire in a spiral, but it would not be convenient to make the conductor of a cable in the form of a continuous spiral. But Pupin showed that if loading coils were introduced at certain intervals, relative to the wave-length, the effect was the same as though the inductance were equally spread throughout the cable. A telephone cable with inductance coils inserted in it every mile or so, is known as a loaded cable, and it is due to this invention that we have greatly improved telephonic communication where long cables are necessary or convenient.

After the publication of Pupin's invention, these loading coils were applied to long-distance overhead telephone lines, and the improvement was very marked. The special interest, however, is in making submarine telephony possible over greater distances. The loading coils consist of rings built up of fine iron wire to act as a core for a coil of silk-wound copper wire.

The engineers hesitated to undertake the laying of a submarine cable having heavy protuberances in it every mile or so. When it was decided to lay a loaded cable in Denmark, the cable was loaded continuously throughout its length, by winding over it many layers of fine iron wire, well insulated from the copper conductor. This plan was adopted in order to simplify the laying of the cable, but the electrical results fell far short of what had been obtained by Pupin's arrangement.

When the British Post Office, in 1910, desired to lay a new telephone cable between England and France, they decided to try a Pupin-loaded cable. This cable required great skill in laying it at the bottom of the English Channel. Special precautions had to be taken in handling the loaded parts of the cable, which occurred about every mile. This cable has proved very successful, but we still await some further advance to enable us to speak by submarine telephone from Europe to America. It seems probable that wireless telephony will make this unnecessary.

AUTOMATIC TELEPHONE EXCHANGES

To any one who has watched the operators in a large Telephone Exchange, it might seem an impossible thing to invent an automaton capable of making all the necessary connections between several thousands of subscribers. But with the opening years of the twentieth century an entirely automatic exchange became practicable.

The pioneer inventors have been Americans, and one of the most ingenious systems is the invention of Almon B. Strowger. His system was adopted in Chicago, and by 1912 there were as many as 30,000 subscribers to the automatic exchanges in that city, while the grand total under the control of Strowger devices was at that time 300,000 subscribers.

In Great Britain we have been making our Manual Exchanges more easily worked by shifting some of the responsibilities on to automatic inventions. For instance, the lifting of the subscriber's telephone receiver lights up a signal lamp indicating to the operator that the subscriber desires to speak. When the operator has put this subscriber through to the other subscriber's instrument, the operator does not require to ring up that subscriber, as the telephone bell rings automatically until the subscriber lifts the receiver to reply. Then, again, when the conversation is finished it is no longer necessary to call off, for when the two subscribers hang up their telephone receivers a lamp glows in front of the operator who made the connection, and the connecting plug may be removed from the jack. In some cases there has been added an automatic cut-out to save the operator the duty of disconnecting at the end of the conversation. It is becoming common practice to register the number of calls automatically by a special meter on the subscriber's line. But the operator still remains to receive instructions and to make the actual connections.

British telephone engineers seem to have been attracted more by semi-automatic exchanges, which are more automatic than is described in the foregoing paragraph, but our present interest is not in the relative advantages between semi-automatic and entirely automatic systems. The latter are of more interest from the invention point of view.

In the Automatic Exchanges there are, of course, no operators at all; there are only mechanical selectors and connectors, which are under the control of the individual subscribers. Instead of a subscriber giving instructions to an operator, the subscriber himself moves a lever on a dial attached to his telephone, and the automatons at the Exchange do the rest.

In the 'two-wire system,' which is perhaps the most easily understood, the subscriber' s dial is marked off in numerals from 1 to 50, and corresponding to each of these numbers is a small hole into which a pin, carried by the indicating lever, may be inserted. The moving of the dial indicator causes a commutator, behind the dial, to rotate one complete revolution for each movement from figure to figure. Each revolution of this commutator sends an electric impulse along the line to the Exchange apparatus. The lever is moved round the dial to the numeral desired, and momentarily locked in that position by inserting the pin into the hole corresponding to the numeral. When released, the lever springs back to zero, and in doing so it rotates the commutator a definite number of times, according to the distance through which the indicating lever had been moved. No matter how slow the subscriber may have been in moving the lever round to the desired number, the actual operation of the commutator is done smartly by the springing back of the lever.

In the earlier dials of the 'three-wire system' there were only ten numerals, 1 to 9 and O. When the subscriber desired to call, say, 5204, he merely pulled the dial round to 5 and let it spring back, then to 2, again to 0, and finally to 4, allowing it to spring back at each move. As already explained, the dial under consideration has 50 numerals. In addition to these, every fifth number is marked off with a letter; A being opposite to 1, B opposite 5, C opposite 10, D opposite 15, and so on. These numerals take the place of the thousands and hundreds in the subscriber's numbers. For instance, instead of a subscriber's number being 1136, it is AA36, and another instead of being 4218 is DB18, and so on. In calling DB18, the subscriber would first move the indicator of his dial to the letter D, insert the pin by depressing the lever, and then allow the lever to spring back. He would then repeat these operations, but taking the indicator to the letter B this time, and then on the next move to the figure 18. At each release of the lever, a definite number of electric impulses reaches the Exchange, and the mechanism by which those impulses make the necessary connections is most ingenious.

First of all the line wire reaches what is called a 'finder.' This is a switch to which 50 incoming line wires are attached. This finder is analogous to an operator ready to respond to any one of 50 subscribers to whom that operator is to attend. The function of the finder is to connect the line of any one of these subscribers to a 'selector,' and this is accomplished in the following manner.

In the finder switch the 50 incoming lines are fixed to 50 contact pieces in an are of a circle. A lever or contact arm can sweep over these, touching each one in succession, as it describes the arc. There is, attached to the finder switch, a vibrating relay, the action of which is similar to that of the gong_ stick in a trembler bell. This vibrating relay furnishes an intermittent current to a motor_ magnet which operates a ratchet wheel and moves the contact arm over the 50 contact pieces, which represent the ends of the subscribers' telephone lines. Whenever any one of the 50 subscribers lifts his telephone receiver off his instrument, the vibrating relay on the finder switch is set in motion, and the contact arm will touch each contact in succession until it reaches the contact to which the calling subscriber's line is attached. Here it finds no earth connection, owing to the subscriber's telephone having been lifted, and the motor-magnet is cut out, leaving the contact arm at rest on the desired telephone wire. In other words, the finder switch has connected itself automatically to the line of the subscriber who is calling, and it is ready to conduct any signals from his dial to the 'first selector' switch in the Exchange.

Of course, this finder switch might be dispensed with if each subscriber's line had a special selector to itself, but this would be analogous to every subscriber to a Manual Exchange having a special operator to attend to that one line.

So far the subscriber has merely lifted his telephone, preliminary to initiating a call, but, without any guidance or even a thought on his part, the finder switch has connected his particular line to a selector. The subscriber now proceeds to signal the telephone number of the subscriber to whom he desires to be connected. This he does, by moving the indicator of his dial, in the manner already described.

But it will simplify matters to form a mental picture of the distribution of all the subscribers' lines in the connecting switches, and it will serve our purpose to picture an Exchange having 5000 subscribers. We have dealt already with a group of fifty subscribers, whose lines are all connected to one finder switch. We may add to our present picture one hundred such finder switches, having in all 5000 lines under control. We have seen that the function of these finders is to connect the calling subscriber to a selector, from which further connections are to be made. Those further operations will be understood more easily if we leave off at this point, and consider the other end of the arrangement, the lines as they leave the Exchange to carry the telephone current to the subscriber being called.

In the first place we picture one 'connector,' from which fifty lines go out to as many individual subscribers. This connector has the fifty lines connected to contact pieces in the form of an arc; indeed, it is just like a finder switch used conversely. In the finder switch the contact arm conducted the incoming current from one of the fifty lines to the selector, whereas in the connector the contact arm conducts the outgoing current from a selector to one of the fifty outgoing lines. As each connector controls fifty subscribers' lines there will be one hundred such connectors to operate the 5000 lines.

These hundred connectors are divided into ten sections of ten connectors each. Tracing the connections leading to the outgoing lines, we find that the ten contact arms of the ten connectors are connected by as many wires to a selector, which, of course, has ten corresponding contact pieces in its arc. As each of the ten sections of connectors has one of these selectors, there will be ten such selectors in all. The ten contact arms of these ten selectors are each connected by a wire to another selector, known as the 'first selector.' This first selector is the one which we have considered already in connection with the finder switch, and to which the finder connects the calling subscriber.

Looking at the whole arrangement now from the caller's end, we picture his line entering one of the finder switches to which it is permanently connected. Then we find the contact arm of this switch linking the subscriber's line to the first selector. The subscriber now signals the first letter, say of the number desired. The impulses sent along the line by this signal cause the motor-magnet on the first selector to move its contact arm to the fourth contact piece, which leads to 'D' switch. The subscriber is now connected through to this particular 'second selector,' and his second signal, say 'B,' operates the motor-magnet in this second selector, moving its contact arm to the second contact piece, which leads to the 'B' connector. The subscriber's line is now connected to the contact arm of the connector in which the line he desires is permanently situated. His next signal, say '18,' operates the motor-magnet of the connector, moving its contact arm around the arc to the eighteenth contact piece, whereupon the two telephone lines are connected together. In this manner the calling subscriber has been 'put through' automatically to the subscriber to whom he desires to speak.

In the foregoing description we have traced all the steps by which any one of the fifty subscribers' lines situated in one finder switch can be connected at will to any one of the total 5000 subscribers' lines. If this were all, it would mean that only one of each fifty subscribers could speak at the same time. So it becomes necessary to provide six finder switches for each group of fifty subscribers, and the arrangement is that any six of the fifty can get through at one time. This permits twelve percent of the subscribers to speak simultaneously, and that is a larger percentage than is possible with the purely Manual Exchange, in which case an operator has only the means of putting ten percent of her subscribers through at one time.

But this multiplication of finder switches means a corresponding multiplication of first selectors; one for each finder. And instead of there being only ten second selectors connected to each first selector, there are forty. The contact pieces for connecting the first selectors to the second selectors are increased accordingly, and the contact arms automatically hunt out a non-busy line. All this arrangement is necessary in order to ensure that a calling subscriber may find a disengaged path all the way through to the subscriber whom he is calling.

It will be observed that the multiplicity of connecting wires in an Automatic Exchange differs from the multiplicity of wires in a Manual Exchange. In the latter it is a case of multiplying the connections of each individual subscriber, so that the whole of the subscriber's lines are repeated and repeated right throughout the multiple-board till each set of operators has a complete set of all the subscribers' lines connected to the Exchange. In the Automatic Exchange, it will be observed that it is the connecting wires that are multiplied, each subscriber's line being taken to one connector only.

Even with all this provision of different paths by which the calling subscriber may be put through to another subscriber, it may happen that the particular subscriber being-called is already engaged. In this case a relay, situated at the connector, will switch on an intermittent current, and the calling subscriber, hearing this engaged signal in his receiver, replaces it, to call up again a little later. It is quite impossible for him to connect his instrument to any other telephone which happens to be engaged.

When a subscriber's manipulation of his signalling dial has put him through to the instrument of the subscriber to whom he desires to speak, he pulls the indicator a short distance and allows it to spring back once more. The consequent revolutions of the commutator attached to his dial energies another relay, which switches on the ringing current to the line to which he has already gained a through connection. The distant subscriber's bell continues to ring until the receiver is lifted in the act of responding to the call. When, at the end of the conversation, the two subscribers hang up their receivers, a releasing relay is operated on each of the pieces of connecting mechanism, and the respective contact arms are moved back to zero, and are then ready to receive impulses from any other subscriber.

It might be supposed that any fault occurring in a finder, a selector, or a connector, would necessitate a considerable delay until repairs were made. But none of these switches have their connecting wires soldered to them; they are fitted with plugs and jacks. If a fault should occur, a mechanic merely pulls out the defective switch and inserts a complete duplicate in its place, leaving the defective one free to be repaired at leisure. In this way two mechanics are able to undertake to keep a large automatic exchange in good working order.

In connection with the Manual Exchanges in this country, we have automatic pay-boxes at public call offices, but the operator at the Exchange instructs us when she is ready to attend to the money-box. She instructs us how many pennies we are to place singly in the box, and we have to turn a handle round for each penny separately. By this simple means we switch on a signalling current to the operator, who, when satisfied with our honesty, connects our line to the line of the subscriber to whom we desire to speak.

In America they have most ingenious money-boxes, which are entirely automatic. The subscribers to the Automatic Exchanges may have these money-boxes attached to their telephone instruments, and pay for each call as they go along, instead of being taxed according to an automatic meter. Suppose that the subscriber to whom he desires to speak is situated outside of the central area, and that there is a charge of ten cents for the first three minutes, and only five cents for each succeeding three minutes. This might seem to be beyond the capabilities of an automaton, but not only will this money-box undertake these duties, it will accept any number of nickels the subscriber may care to place in its hopper, and at the end of the conversation it will return to him any money not required for the length of conversation which has taken place.

The money-box holds the nickels in trust for the calling subscriber until the distant subscriber responds by lifting the receiver from his telephone. Thereupon the hopper device automatically drops ten cents from the pile of nickels into the bottom of the box, and the subscribers can converse together. At the end of the first three minutes, a disc at the central office makes contact and causes other five nickels to drop into the bottom of the box, leaving the line connected through for other three minutes. At the end of the next three minutes the same operation takes place, and will be repeated so long as the subscribers keep their telephones off the hooks, and so long as the money lasts.

If it happens that the telephones are replaced before the money is exhausted, the money-box will automatically open and deposit the remaining coins on a tray beside the subscriber. If, on the other hand, the subscriber has not put sufficient nickels in the hopper, the automaton does not disconnect him, without first of all giving him an opportunity of adding the necessary coins. If it did, he would have to initiate a new call at the expense of ten cents, in place of five, for the next three minutes. Suppose lie has anticipated only a conversation of three minutes, but at the end of that time he is still engaged in conversation, and the money in the hopper is exhausted. In this case his line is left through, but he hears his friend asking where he has gone, as he cannot hear him. The subscriber realises that his time is up, and that he must deposit more nickels in the hopper. As soon as he does so, the hopper counts out five cents for the box and then allows him to continue his conversation for other three minutes.

The trunk charges to certain districts may be at reduced rates after a certain hour in the evening; but the automaton can deal with this case also. The subscriber finds that in these circumstances his money-box does not call for a second payment until the end of a six minutes' conversation, and so on. To accomplish this, all that is necessary is that the mechanic at the Exchange turns a certain switch at a certain hour, and even this could be done automatically by clockwork if desired.

CHAPTER III

MORE ELECTRICAL INVENTIONS

METALLIC FILAMENT LAMPS—THE FLAME ARC—MERCURY VAPOUR LAMPS—A STATIC CONVERTER—LIGHT-TRANSFORMING REFLECTOR—SILICA LAMPS—A ' WIRELESS' TRANSMITTER AND RECEIVER—CARDIOGRAPHIC APPARATUS—RAILWAY AUDIBLE CAB SIGNAL.

ELECTRIC LAMPS

In the realm of Electric Lighting there have been several remarkable inventions since the beginning of the present century, but some of these do not call for much description. Indeed, so far as the metallic filament lamps are concerned, the chief interest lies in scientific discovery, and in the processes of manufacture.

The invention of metallic filament lamps consisted in substituting a metal for a carbon filament; but to do so was not an easy matter. The idea was older than the carbon filament lamp itself, as the first attempts at incandescent lighting were made with filaments of iron, platinum, and platinum-iridium. It was found that these metals had to run so near their melting-points that the carbon filament was far superior.

Recent scientific discovery showed how some of the rare metals, formerly only known in the chemists' laboratory, could be separated and worked on a practical scale. These metals are capable of withstanding very high temperatures. The melting-point of platinum is 2000° C., whereas one of these rare metals, tungsten, is as high as 3200° C.

At present our interest does not lie in the manufacture, but it may be noted that there are several methods of producing these metallic filaments. The first process was to make them from a paste, very much after the manner of the carbon filaments. The metal is reduced to a finely-divided state and made into a paste with gum, dextrine, or other binding material. This paste is then squirted through a very fine orifice in a diamond, under a pressure of several tons per square inch. The result is a fine moist thread, which is dried by heating in a vacuum, after which the binding agent has to be expelled. This is done by raising the filament to a very high temperature in an atmosphere of gases, whose chemical elements will unite with the elements of the binding material, and leave the pure metal intact. The fine metallic filament, which measures about one-thousandth of an inch, approximately as fine as a human hair, is placed in position in the vacuum glow-lamp.

In sonic cases the filament is made from pellets of the metal, and with modern wire-drawing machinery it is possible to draw the metal out to a filament of one-thousandth of an inch in diameter. Another method, which is used in connection with tungsten lamps, is to deposit the metal on fine carbon filament, by heating the latter in the presence of chloride or oxi-chloride of tungsten. The carbon is driven out, later, by heating the filament to a very high temperature in an atmosphere of damp hydrogen. These lamps have an efficiency of 1 watt per candle-power, whereas the nineteenth century carbon filament lamps consumed energy at the rate of from three to three and a half times that amount.

Another interesting invention in the same field is the 'Flame are,' or as it was called at first, 'Long-flame are lamp.' The electrodes in these have certain salts mixed with the carbon; the addition of the salts of fluoride, bromide, and iodide of lime give the light a yellow tint, while other salts of lime produce a red colour. Salts of calcium, magnesium, and strontium are used, and also the borates of soda and potash. The effects are very much more pleasing than the bluish-white glare of an ordinary arc lamp. But the chief value of the invention is not in providing a more pleasing light; the advantage lies in the production of an arc about five times as long as that produced between simple carbons. The flame arc lamps produce about twice as much light as the ordinary arc lamp for the same consumption of electrical energy.

Yet another outstanding invention in electric lighting is the mercury-vapour lamp. In 1901 a mercury-vapour lamp was shown as a curiosity at a social gathering at Columbia University (U.S.A.), and a few years later it became a practical success.

It may be mentioned in passing that mercury vapour was connected with our first knowledge of electric light, if we exclude the simple electric spark. More than two hundred years ago an experimenter happened to shake an imperfectly exhausted barometer tube, whereupon there appeared a luminous glow within the tube. It was soon recognised that this luminosity was due to friction between the particles, producing a state of electrification.

The Cooper-Hewitt mercury-vapour lamp consists of a vacuum tube with mercury for one of its electrodes, and iron for the other. When the current is passing through this tube, the mercury is vaporised and becomes incandescent. In order to start the lamp it is necessary to place the electrodes in contact, just as is the case in ordinary arc lamps. In the mercury-vapour lamp this is accomplished by tilting the lamp until the mercury runs over in a stream to the second electrode, making a temporary bridge for the current. The tilting of the lamp may be done automatically if desired. In this case, when the current is switched on, it passes through an electro-magnetic arrangement and back to the mains. In this short circuit the current passes through a solenoid, a cut-out, a substitutional resistance, and through a series resistance back to the mains. When this short circuit is energised the solenoid tilts the tube, and as soon as the current finds the parallel circuit through the stream of mercury it energizes an inductive resistance (in series with the tube), and this operates the cut-out. The tilting-solenoid being cut out, releases the lamp, which falls back to its normal position by gravity.

While this lamp gave a very economical light, consuming only one-half watt per candle-power, it had a distinct disadvantage in being devoid of red rays; a piece of scarlet cloth would appear black in its light. But in 1910 the inventor added a light-transforming reflector to compensate for this defect. This consists of a reflector, which diffuses the light, and the surface of the reflector is coated with a translucent material containing a fluorescent substance. The fluorescent substance has the effect of reducing the frequency of the waves, just as X-rays can be translated into visible light by means of a fluorescent screen. In this way some of the wave energy is stepped down into the red and orange portions of the spectrum, and this reflected light added to the direct light of the lamp produces quite natural colour effects.

The usual form of a Cooper-Hewitt lamp is a long tube measuring 18, 26, or 38 inches respectively. This is done in order to utilize voltages from 100 to 250 volts; but a shorter tube has been invented, and this may be enclosed in a globe similar to an ordinary arc lamp. This short mercury-vapour tube is made of quartz, and is known commercially as the Silica lamp. While quartz will stand a very much higher temperature than glass, the substitution of quartz for glass placed the manufacturer in a serious difficulty. He has no difficulty in conducting the electric current to the inside of a glass vacuum tube by means of platinum wires. Platinum and certain kinds of glass have practically the same coefficient of expansion for heat, so the seal will not break down when the lamp heats or cools. The expansion of quartz and platinum, however, are very different. The expansion of quartz is almost 0.4 micron per degree per unit length, whereas the expansion of platinum is 8.0 microns. (A micron is one-thousandth part of a millimetre, or one-millionth part of a metre.) With this ratio of 1 to 20 it is impossible to make a satisfactory seal; it is sure to break down almost at once.

This expansion difficulty was overcome by the invention of an alloy of steel and nickel, which the inventor, C. E. Guillaume, has christened 'invar.' This alloy expands 0.8 micron per degree per metre, and is thus very similar to that of quartz. Although invar gets over the expansion difficulty, it does not permit of a simple seal as is done with platinum, for invar is a forged metal which loses its properties when brought to red heat. To overcome this difficulty, a tapered rod of invar is ground into a conical quartz tube, and this mechanical seal is protected by a mercury cup, the mercury being retained by bitumen or cement.

Mercury lamps, being very rich in ultra-violet rays, have been used for sterilizing water, the rays being death to the bacteria. Another department into which the mercury vapour lamp is being introduced is that of electroculture. The radiations from the lamp stimulate vegetable growth.

A distinctly different use to which the lamp is put is that of a 'static converter," to convert an alternating electric current into a direct current. The lamp practically stops the negative impulses of an alternating current, and permits the passage of positive impulses only. When the lamp is used for this purpose it is provided with several positive electrodes, and the tube is made spherical in order to provide a larger area for dissipating the heat in the apparatus. Another advantage in the spherical tube is that the distance between the positive and negative electrodes is lessened, thus reducing the waste of current. By means of a mercury arc rectifier it is possible to charge accumulators from an alternating current circuit.

WIRELESS INVENTIONS

As Wireless Telegraphy had scarcely gained a business footing until the beginning of the present century, it is natural that all the more important practical inventions connected with it fall within our present field of inquiry; but the subject is so wide and of such general interest that there is to be a special volume, in the present series, on Wireless Telegraphy. For our present purpose it will be sufficient to consider one wireless transmitter and one receiver.

From the simple spark-discharger, there was evolved in 1907 a large synchronous disc-discharger. This transmitter produces a series of tether waves, which set up a distinct musical note in the distant receiver. In this way the interference of atmospheric disturbances, or discharges from other stations, are distinguished easily from the particular signals transmitted from this synchronous transmitter.

When attempts were made to produce a musical note, using fixed electrodes in the discharger, it was found very unsatisfactory, owing to the formation of an arc between the electrodes. This difficulty was overcome by inserting between the electrodes a toothed wheel, which was rotated at a high speed. The sparks had to pass from one electrode to the insulated wheel, and from that to the second electrode. This prevented any continuous arc being set up.

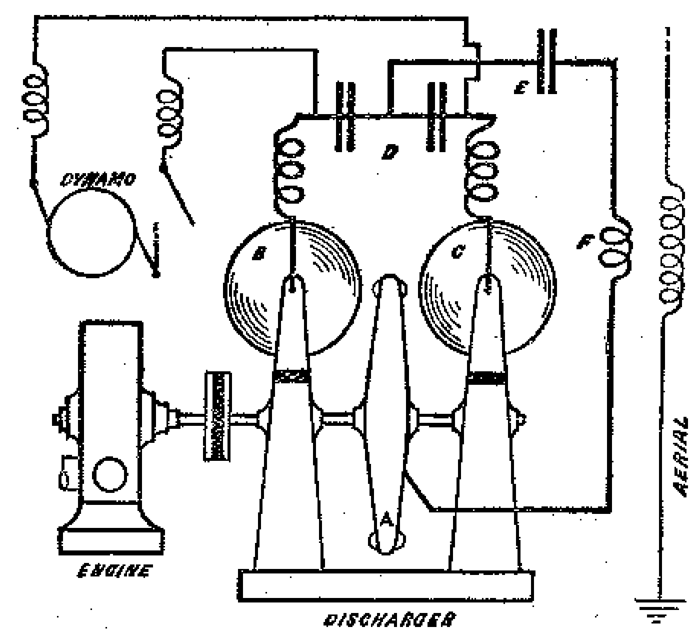

FIG. 1: A TRANSMITTER IN WIRELESS TELEGRAPHY.

We may picture the toothed wheel being replaced by a large insulated metal disc, with a number of studs projecting from it, so that the circle of studs will pass between the electrodes as the disc revolves. In place of two fixed electrodes we picture two smooth metal discs placed at right angles to the surface of the large disc, so that the revolving disc passes through between the two edges of the electrode discs, as shown in Figure 1.

The dynamo charges the condenser D and the revolving discs B and C, and these discharge through the projecting studs on the large revolving disc A, which is insulated. This charges and discharges the condenser E through the inductance F, and these to and fro impulses induce a similar electrical disturbance in the aerial, which in turn passes the energy out into the ether of space, in the form of groups of 'wireless' waves. The smaller discs are kept revolving also. These electrode discs are connected to a high-tension generator, and the discharge takes place as described.

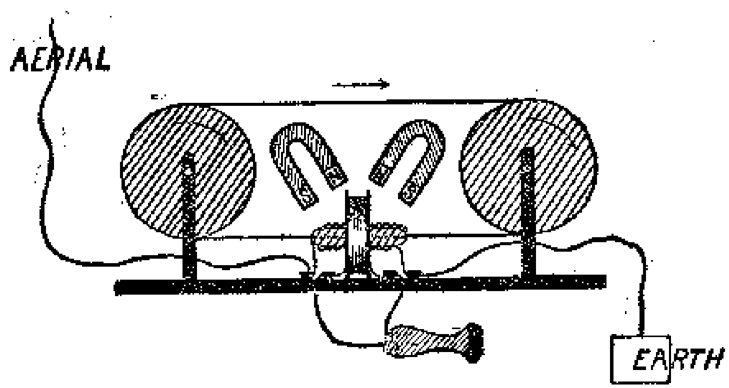

FIG. 2: A RECEIVER IN WIRELESS TELEGRAPHY.

In the latest machines the number of studs on the disc are the same as the number of poles in the generator (alternator), thus giving one spark in every half-cycle. Prior to this synchronized arrangement, the disc studs passed the electrodes about five or six times in each half-cycle of the generator current, but the results were not nearly so satisfactory. We picture this wireless transmitter sending out groups of tether waves, which, arriving at the receiver, produce a clear musical note.

A well-known form of receiver is the Marconi Magnetic Detector. Its general appearance is not unlike that of the telegraphone (page 53), but the two inventions have entirely different functions. In the magnetic detector there is an endless band of insulated iron wires, which are kept in motion by passing over two revolving pulleys (see Figure 2). A temporary state of magnetization is produced in that part of the iron band passing in close proximity to the two permanent magnets. The band being made of soft iron, there is no permanent magnetization in it. Indeed, the magnetic polarity of the different parts of the iron band will keep changing continuously as they approach and recede from the magnetic poles, and it is well known that this change requires time. The change in the iron will lag behind the application of the magnetic force, the phenomenon being known as 'hysteresis.' The change may be hastened by the influence of a neighbouring electric current, and this occurs in the following manner:

A wire leading from the aerial is wound around a small glass tube, through which the iron band passes at the moment when it is under the influence of the permanent magnets. This aerial wire is then led to earth. Any electric impulses in the aerial will hasten the magnetic changes in the iron. The electric impulses in the aerial will correspond with the electro-magnetic waves arriving through space from the distant wireless transmitter. The sudden changes of magnetism in the iron band will induce electric currents in any suitable surrounding coil of wire. Such a coil or bobbin of fine wire is placed, as shown in the diagram, around the magnetised portion of the band. This bobbin of wire is connected to a telephone receiver, in which a sound will be heard at each sudden change of magnetism in the moving band. And if the transmitter is sending out regular groups of waves of a suitable frequency, there will be heard a distinct musical sound.

The connection between the distant transmitter and the receiver is easily followed. By means of a special telegraph key the sending operator controls the electric impulses sent out by the transmitter. These impulses or waves pass out through the anther of space, and some of them are trapped by the aerial. The electric disturbance in the aerial wire affects the magnetic condition of the iron band, and the sudden magnetic changes induce momentary currents in the telephone circuit, and by the sounds in the telephone the Morse signals may be read.

CARDIOGRAPHIC APPARATUS

The function of Electrocardiographic apparatus is to register the pulsations of the human heart. Experiments made upon the freshly extracted hearts of frogs and tortoises have shown that there exists a natural electric current, which varies as the auricle and ventricle of the heart contract in succession. The electric current is, of course, a very weak one, but its variations may be read by means of a string galvanometer.

The string galvanometer was invented by Professor Einthoven, of Leyden, and consists of a very fine silver-plated filament of quartz, measuring about one-twelve-thousandth part of an inch in diameter. The quartz thread is stretched at right angles to the lines of force between the poles of a powerful magnet. The incoming electric current on passing through the filament sets up a magnetic field around it, and the filament is influenced by the powerful magnetic field of the neighbouring electro-magnet; the middle of the conducting filament is deflected at each electric impulse. In order that the movements of the filament may be read, a greatly magnified image of it is projected upon a photographic plate or sensitized paper. By means of an arc lamp and a lens, light is sent into the dark-box through a lateral slit. The filament of the galvanometer is placed so that a shadow of it is projected upon the sensitized surface within the dark-box. Movement is given to the photographic plate or paper, and a record of the deflections of the filament is made.

At first it was thought necessary to place the terminals of the recording apparatus in contact with the patient's chest, one terminal over the apex and the other at the base of the heart. But it has been found that it is possible to conduct the current from the hands of the patient, who immerses his hands in two vessels filled with salt water and connected by conducting wires to the galvanometer. In the latest arrangement there is a third lead taken from the patient's left foot placed in a third vessel of salt water. A separate record is taken from each of these three leads. We may picture the human heart as a battery or a dynamo sending out impulses at regular intervals. These electric impulses are conducted to the filament of the galvanometer and thence to earth.

The apparatus consists of these water-vessels which act as terminals for the wires which have to lead the heart impulses to the sensitive string galvanometer. An arc lantern projects the shadow of the pulsating filament upon the photographic plate or paper-ribbon. If a sensitized glass plate is used, and this is the most convenient for general purposes, the plate is held in a compound slide, enabling any desired fraction of the plate to be exposed at a time. The plate, which measures 85 x 170 millimeters (3.25" x 6.5"), slides downward by gravity, and its speed may be adjusted to any value between 1 and 100 millimeters per second.

In the continuous-paper camera there is a reel of bromide paper about 75 meters long and 80 millimeters wide. It is driven by means of a small motor, and can be made to travel at speeds from 15 to 180 millimeters per second. The horizontal lines are photographically ruled at 1 millimetre intervals, while the vertical lines are obtained by means of a simple tetanus time marker, the intervals representing fiftieths of a second.

The transmission between the patient and the recording apparatus being electrical, it is possible to convey the impulses to a distance. For instance, Professor Einthoven had a recording apparatus in his laboratory connected by cable to the salt-water-vessels in the Leyden Hospital, about a mile distant.

RAILWAY AUDIBLE CAB SIGNAL

In the first year of the present century not a single fatal accident occurred to any passenger on British railways, but it has not been possible to maintain this record. Recent disasters seem to call for some automatic means of preventing an engine-driver running past a danger-signal, and so we are naturally interested in any reliable means of achieving that end. The Railway Audible Cab Signal has passed the experimental stage, and is in continual service on 1.10 miles of track on one of the principal English passenger main lines, also on a branch line, where it has replaced distant signals, and several other principal railway companies are seriously considering the adoption of this essential safeguard.

Instead of the driver and fireman having to keep a look-out for the distant semaphore signal, or its light, they may have the signal given in the cab of their locomotive. A dial placed in front of them beside their starting-lever and valve-handles, shows a white signal when the way is clear, and this is replaced by a red ground, on which the word 'Danger' is painted, when the way is not clear. There is a further safeguard to prevent the signal being overlooked. The moment the signal 'Danger' is given, a steam siren or whistle is sounded in the cab, and it will not stop until the driver lifts a lever. In order that the driver may know when he passes the distant 'All Right' signal, an electric gong is sounded, and continues to ring until the driver presses a push. It might seem quite unnecessary to add any further safeguard, but in addition the brakes may be applied automatically if the train should attempt to run past a danger signal.

At each place where it is desirable to give the driver an audible signal, a 'ramp' consisting of a bar of T iron, suitably mounted and insulated on a timber base, is fixed in the centre of the track. This ramp is connected by electric wires to the signal cabin, and if the way is clear the pulling of the 'All Right' signal-lever switches on an electric battery current to the ramp. From what follows it will be seen that the presence of this current causes the electric gong to sound and the white signal to remain visible in the locomotive cab. But when the signalman pulls his 'Danger' signal-lever, no current is sent to the ramp, and the siren sounds, the visible 'Danger' appears on the dial, and the brakes are applied.

It is clear that the locomotive must be put in electrical connection with the ramp, and this is done very easily by means of a sliding contact. The ramp, which is about sixty feet in length, is slightly arched, its two ends being at rail level and its centre rising four inches higher. The ramp is, of course, a fixture, and has no moving parts whatever. A shoe is fixed beneath the engine and in position to engage with the ramp. When passing over the ramp the shoe is raised one-and-a-half inches. The shoe is insulated from the mass of the locomotive, and in its normal position the shoe is held down by a spiral spring. When in its normal position the shoe closes an electric circuit on the locomotive, and a local battery current keeps an electro-magnet energised. This magnet holds up a lever which keeps the steam whistle closed, but when the shoe is raised by passing over the ramp, this electric circuit on the locomotive is broken, and the magnet lets go the lever, causing the whistle to sound and, at the same time, releasing the red 'Danger' signal on the dial.

This danger signal will be given every time a locomotive passes over a ramp, unless the signalman sends an electric current to the ramp, in order to prevent the danger signal being given; this is done automatically when he pulls the 'All Right' signal-lever. When the shoe picks up the electric current from the ramp the current energizes a polarized relay which completes another circuit to the electromagnet and holds up the lever, although the direct normal circuit to the electro-magnet has been broken by the raising of the shoe, and so the whistle is still kept closed and the visual 'Danger' signal is not released. At the same time, the electric current from the ramp operating the polarized relay also switches on the local battery current to the electric gong, which continues to ring until the circuit is broken by the driver pressing a push. It will be observed that, should anything go wrong with the signalman's connection to the ramp, or should he fail to give the 'All Right' signal, the engine-driver will receive the danger signal, for the shoe will be raised, breaking the local circuit on the locomotive and releasing the audible and visible danger signals, and simultaneously applying the brakes.

This system necessitates the provision of a continuous electric current on the locomotive to maintain the 'All Right' signal, but all that is required is a battery of four small dry cells. The cost is infinitesimal compared with the great safeguard provided. Should the current from these cells fail, the electromagnet will cease to be energised, and it will let go the lever causing the danger signal to be given.

In order to save the current while the locomotive is in the shed, there is an automatic arrangement by which the battery current is switched off whenever the steam in the locomotive boiler falls below 20 lb. pressure, the current being automatically switched on again when the steam rises to that pressure.

It requires no very lively imagination to appreciate the immense advantage in this audible cab signal in case of foggy or dirty weather, and it prevents any possibility of a driver omitting to observe a signal while he is attending to the mechanism of his engine. The safeguard is so great that the man-in-the-street will wonder that the use of such apparatus is not made absolutely compulsory.

During recent years there has been a host of inventions in connection with the automatic operation of railway points and signals, and it was the introduction of these which made it possible to accelerate the train service on the London Underground Railways. All this necessitates considerable expense, but the reduction in the number of signal-cabins is great, and in some cases one automatically-operated cabin replaces as many as thirteen manual cabins.

CHAPTER IV

MOTIVE-POWER INVENTIONS

AN EXPLOSION PUMP—A 'VALVELESS' MOTOR—VALVELESS GAS ENGINE—A ROTARY ENGINE—SUN-POWER PLANT.

AN EXPLOSION PUMP

Although the idea of an explosion pump is not new, the Humphrey pump, invented in 1906, is not only novel but forms a complete revolution in the methods of raising large quantities of water. So great is the novelty that when the inventor (Herbert A. Humphrey) read his first paper on the subject to the Institution of Mechanical Engineers, London, Professor C. Vernon Boys said he had felt from the beginning very much in the position of the undergraduate to whom a coach had explained the principle of the siphon. After listening with admiration, the undergraduate said, "Yes, sir, but will it really work?" The author's pump was one of those things which, had he (Professor Boys) had the good fortune to think of it, he would have had some doubt in trying, because he would hardly have believed that it would really work in the most beautiful way in which the author had shown that it actually did.

The outstanding novelty in the Humphrey pump is that it has no piston and no connecting-rod. A column of the water itself acts as the piston. The general arrangement is not unlike a large U tube, the one leg of which is closed at the top to form an explosion chamber above the surface of the water in the tube, the space above the water in the second leg being perfectly free. An explosion of a gaseous mixture in the confined space in the first leg will force the water down that leg and up the other one. We may imagine some of the water overflowing at the free end, and the remainder falling back in the tube and rising again in the first leg. In doing so it will compress the waste gases resulting from the explosion, and when the column of water has expended its kinetic energy, the compressed gas will react and force the column of water to rise again in the second leg; the column of water would behave like a pendulum until its energy was dissipated.

To convert such an arrangement into a pump, we should require some inlet of water into the U tube, an escape for the exploded gases, an automatic inlet of a fresh explosive mixture, and an automatic ignition apparatus.

The accompanying diagram shows the general principle of the Humphrey pump. The inlet of the water is obtained through a simple water valve box, so arranged that the static pressure of the column of water in the discharge pipe keeps the water valves closed. When the column of water makes its forward swing under the pressure of the explosion, the water-pressure upon the valve box will be withdrawn, the level in the pump pipe will fall below that in the supply tank, and water will flow from the supply tank to follow the moving column of water, and also to rise up into the explosion chamber, to fill the partial vacuum produced by the gases having expanded beyond atmospheric pressure. There will also be a tendency for the water to rise to the level of the supply tank. It may be observed in passing that this gives a convenient means of controlling the amount of water to be permitted to enter the pump at each stroke. If the level of the water in the supply tank be raised, there will be a corresponding increase in the amount of water admitted, and so on.

Suppose there has been an explosion, forcing the great column of water forward and up the water-tower. At a point some distance below the water-level in the tower the outlet pipe branches off. Of course, the water might be made to discharge as an overflow at the top of the tower, but then its flow would be spasmodic, being only on the forward or upward stroke, whereas with the arrangement just described there will be a continuous flow, as water will enter the outlet pipe on the downward as well as the upward stroke. As soon as the column of water commences to travel backwards, the static pressure of the water will close the valves of the supply tank.

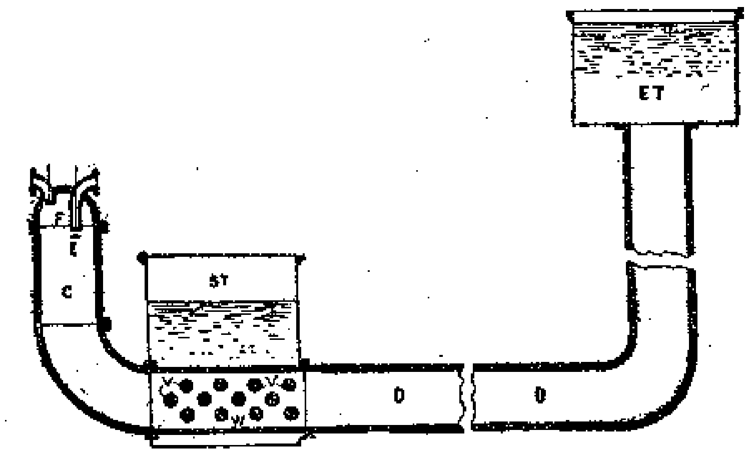

FIG. 3.

HUMPHREY EXPLOSION PUMP.

S T Supply tank from which water has to be raised.
E T Elevated tank.
D Discharge pipe.
W Water-valve box.
V Valves which open inwards.
C Combustion chamber.
A Inlet valve.
E Exhaust valve.
F Cushion space for imprisoned gases.

FIG. 3: HUMPHREY EXPLOSION PUMP

At the forward motion of the great water piston, resulting from the explosion, the exhaust valve is mechanically released and falls by its own weight. The waste gases are therefore expelled by the backward rush of the water, until the water reaches the exhaust valve itself and closes it by impact. The exhaust valve is placed at a lower level than the top of the explosion chamber, in order that some of the gases will be entrapped in the head of the chamber and will act as a compression cushion.

If this gaseous cushion were composed entirely of waste gases, they would detract somewhat from the efficiency of the next explosion. The explosion chamber is therefore provided with a scavenger valve, through which fresh air is drawn in, so that the compression cushion is composed chiefly of air.

When the compression of this air cushion has taken up the energy of the great water pendulum, the compressed air forces the water forward once more. It is not the exhaust valve which opens this time, for a sliding-lever having moved below a collar on the valve spindle, locks it and prevents it falling, as was the case at the first stroke. The other end of this sliding-lever has released the inlet valve for the explosive mixture, so that the second forward stroke of the water piston draws in a fresh charge of gas and air.

The second return or backward stroke of the water piston compresses the explosive mixture, and also operates a small piston which controls the ignition apparatus. This is so arranged that at the moment the compression has reached its maximum and the reaction has commenced, electrical contact is made and the mixture is fired by an electric spark.

On the long outward stroke of the water piston, resulting from the explosion, we have the opening of the exhaust valve and the scavenger valve; the spent gases are expanded beyond atmospheric pressure and fresh air is drawn in. Then follows the long return stroke, the backward swing of the water piston, which expels the waste gases, closes the exhaust valve, and compresses the air cushion in the head of the explosion chamber.

The pressure of the rising water in this long return stroke operates a relay which moves the interlocking rod in one direction, locking the scavenger and exhaust valves, and unlocking the gas valve. This leaves the gas valve free to act, against a supporting spring, on the second outward stroke of the water piston.

The pressure of the rising water in the second or short return stroke causes the relay to move the interlocking lever in the opposite direction, so that the gas valve is locked while the scavenger and exhaust valves are unlocked, and left ready to act on the next forward stroke. This simple see-saw motion locks and unlocks the two sets of valves alternately.

Public attention was directed to this invention when King George, accompanied by the Queen, performed the opening ceremony of the new pumping station at Chingford. This station was to raise 180,000,000 gallons of water every twenty-four hours, from the River Lea to a large reservoir some twenty-five to thirty feet above the level of the river at that point.

The Metropolitan Water Board had found this a serious problem to face, as the cost of pumping so large a quantity of water was going to prove excessive. While they had the problem before them, H. A. Humphrey happened to read his paper before the Institution of Mechanical Engineers, and his Pump and Power Company were invited to put forward a tender for the large pumping station. When the different tenders were opened, it was found that the Humphrey Pumping Station would cost £19,000 less than the lowest offer for a steam-driven centrifugal pumping plant. Further, the cost of fuel for the steam plant was two or three times more than the consumption estimated for the explosion pumps.

So far no explosion pump had been made greater than 35 horse-power, whereas at Chingford there were to be four pumps, each developing between 200 and 300 horse-power, and a fifth pump of about half that power. There was, therefore, little practical data to go upon; and in order to safeguard the interests of the Board, the condition upon which the inventor's tender would be accepted was a penalty of £20,000 in case of failure. The inventor was not only willing to give this guarantee, but also accepted the condition that if his consumption of fuel exceeded the 1.1 lb. of anthracite estimated to produce one horse-power, he was to pay a penalty of £1000 for every one-tenth of a pound exceeding the estimated amount.

There was a delay of nearly one year in getting this pumping station ready for work, and in some quarters a suspicion arose that the new invention was not working out on a large scale in the manner predicted by the inventor; but the whole delay was due to the Water Board not having been able to get the buildings for the pumps ready earlier owing to pressure of other work. So carefully was all designed that the only detail altered, as the result of seeing the huge pumps at work, was the substitution on certain valve spindles of a solid nut instead of the split one originally provided. Fortunately the pumps proved a complete success, and instead of penalties there was nothing but praise.

The speed of this pumping engine will, of course, be controlled by the swing of the great water pendulum, and that again will be dependent upon the length of the column of water, which may be altered at will by altering the length of the discharge pipe. Other things being constant, the period of oscillation is almost proportional to the square root of the length. With the diameter of the discharge pipe (which may be described also as the play pipe) 2 feet, the maximum velocity of flow permitted 14 feet per second, the length of pipe 50 feet, there will be 31 cycles per minute. By doubling the length of pipe, the number of cycles is nearly halved, being 14.3 per minute. The length of play pipe usually adopted is from 60 to 80 feet. The diameter of the play pipes in the Chingford plant is 7 feet.

The starting and stopping of the pumps is very simple. If the pump is at work and it is desired to stop it, all that is necessary is to switch off the electric current which operates the sparking coil. The water piston will come to rest with a fresh charge of gas and air in the explosion chamber, and the mere switching on of the electric current will ignite this and start the water piston once more. If desired, the pumps may be controlled from a distance.

In starting the pump up for the first time, all that is necessary is to use compressed air with the gas, and so depress the water level a little below the usual charge volume. If the exhaust valve is then forcibly opened, the water will rise in the chamber and compress the explosive mixture, and all is ready for the switching on of the electric current.

At the meeting of the Institution of Mechanical Engineers, when the inventor read his paper upon explosion pumps, Professor C. V. Boys said that perhaps the most surprising part of the pump or engine, as compared with any other machine yet made, was the fact that, when all was cold and at rest, one touch of the button instantaneously started the machine going at full speed. No other engine was in any respect like that.

It is evident that there can be no rotary governors to control the inlet valve, but a throttle valve may be controlled by the pressure or height of the water, and either the mixture or the gas alone may be governed according to the power developed. On the other hand, the pump may be allowed to work at maximum capacity, and a float on the high-level tank may serve to cut off the ignition and switch it on again as the water rises and falls between two fixed levels.

Without going into further detail, it may be mentioned that while the pump described is a four-cycle pump (two outward and two inward strokes in each complete cycle), it is quite convenient to construct a two-cycle pump, and that this may be done without the aid of outside pumps to draw in the gas and air and to force them into the explosion chamber, as has to be done in the two-cycle gas engines.

It may be mentioned also that the Humphrey pumps can be converted into high-lift pumps by means of air vessels fitted with valves being added at the end of the discharge pipe. A small air vessel is placed at the entrance to the large air vessel into which the high-pressure water is to be delivered. The inlet into the large air vessel is fitted with a non-return valve, which remains closed until the inrush of water into the small air vessel has compressed the air therein sufficient to open the valve. The energy of the water column is then spent in delivering water in the larger vessel, and any backflow from it is prevented by the valve closing. This would leave the water-pendulum without sufficient potential energy to compress the next combustible charge on the return stroke, but there is sufficient energy in the compressed air in the small air vessel to make good this deficiency.

The inventor does not believe that his internal combustion pump will be confined to pumping water from one level to another; he is confident that there is a very wide field of operation. He is not alone in that belief, for at the meeting of the Institution of Mechanical Engineers, already mentioned, Professor Henry J. Spooner said, "If the internal combustion pump proves in the future to be a successful competitor of the gas engine for power purposes, then it is probable that one of the most useful fields for its employment will be found in the propulsion of ships. Quite apart from the possibility of driving a turbine attached to a screw-propeller, there is the jet-propeller, which is the most efficient of all propellers for ships if properly constructed and operated. What has been lacking so far has been a type of pump capable of delivering very large quantities of water at comparatively low heads, and it is just these conditions which suit the author's pumps in their simplest form." The inventor does not have visions of jet-propelled Atlantic greyhounds, as this system of propulsion is not suitable where high speed is essential.

Of course the field for the invention as a prime mover would be unlimited, and although there would be a loss of about twenty percent due to the introduction of the water turbine, the inventor has a good deal to spare in the way of cost, while the column of water which takes the place of the piston, the flywheel, and the connecting-rod, requires no lubrication and has no working parts to go out of order.

Another field open to the explosion pump is the compression of air, and the inventor suggests in this connection that blast-furnace gas might be used in an explosion pump, which could take the place of the blowing-engines for producing the blast.

In closing his remarks in the discussion at the meeting of Mechanical Engineers, Professor C. V. Boys said in a playful manner that he had wondered to a certain extent how it was that the inventor had been inspired. No doubt the members had their own theories on the question, but personally he had wondered whether the inventor, when he had seen large pipes lying about in the Mond gas stations, which were not just then required for the purpose of conveying gas, had quietly put them on end, without being seen, and converted them into a big telescope, and had discovered the physical cause of water travelling at the rate of two miles an hour in the canals of Mars, as had been observed by Dr Lowell. It was quite clear that the water in the canals of Mars could not travel at the speed of two miles an hour in virtue of any other physical cause than by the aid of such a pump as the inventor' s. If he had observed this, he was still the inventor from the English Patent Office point of view; he was the first importer of the invention on this Earth.

KNIGHT 'VALVELESS' MOTOR

The invention of what has been called a 'valveless' motor was made by Charles F. Knight, of Chicago, about 1908. It is not really valveless, but it has no valves of the orthodox make. The supply and exhaust pipes are opened and closed by means of two concentric sleeves, with slots in them. The sleeves slide up and down between the piston and the cylinder walls, movement being given to them by connecting-rods, whose lower ends are operated by eccentrics carried on a small shaft. The eccentric shaft is driven positively, by a silent chain, from the main shaft, and rotates at one-half the speed of the motor.

It is not difficult to picture the operation of these two sleeves, each going through a definite cycle of movements under the control of its eccentric. When the piston is at its top centre, and is starting downward on its inlet stroke, the inner sleeve is at the lowest point of its travel, and is commencing to move upward. In this position its slot, in moving upward, is commencing to uncover the opening of the inlet. The outer sleeve is about midway in its downward travel, and its slot has commenced also to uncover the inlet. As the sleeves are moving in opposite directions to one another, the one slot is uncovering only the bottom of the inlet opening, while the other is uncovering only the top, so that the whole inlet is still completely covered by some part of each sleeve. But as the one eccentric pushes the inner sleeve upward, while the other eccentric pulls the outer sleeve downward, there comes a time when both slots are exactly opposite the inlet, and a supply of the gaseous mixture from the carburetor enters the cylinder. At this point the piston is a little more than half-way down on the suction stroke, so the gases are drawn in. The outer sleeve has reached its lowest travel, and is moving very slowly, but the inner sleeve is moving rapidly and the inlet is quickly closed. During this time the exhaust outlet has been closed by the combined sleeves.

While the piston is making its compression stroke, the inner sleeve continues to move upward; the inlet and exhaust are, of course, closed while the explosion occurs. When the piston is about two-thirds of the way down on the explosion stroke, the exhaust outlet commences to open. The inner sleeve is moving downward, and as it goes its slot will uncover the exhaust, the outer sleeve being practically stationary at the top of its stroke, with its slot almost right opposite the outlet. As the outer sleeve starts on its downward move, and gaining in speed as the inner sleeve loses, the exhaust is first uncovered and then closed by the time the piston has completed its upward exhaust stroke. The timing of the sleeves by means of the eccentrics is ingenious, and may be altered by varying the 'lead' between the eccentrics and by properly locating the slots in the sleeves. By the time the eccentrics have gone through a complete cycle of operations, the crank has turned twice, giving the four cycles (suction, compression, explosion, and exhaust).

In a motor in which the piston has a 5 1/2-inch stroke, the travel of the sleeves is only 1 1/2 inch, hence the movement of the sleeves is leisurely compared to the fast-moving piston, which has to make two of its longer strokes to one of the short strokes of the sleeves. The efficiency of this motor is very high.

VALVELESS GAS-ENGINES

In a paper read before the Iron and Steel Institute, at Leeds, October 2, 1912, Alan E. C. Chorlton described his invention of a valveless gas-engine. It has the appearance of a triple-expansion steam-engine; but what appears to be one of the cylinders is the ordinary air and gas pump arrangement. The other two cylinders are in reality one double or 'duplex' cylinder, for they are connected at the top and at the bottom. There are no valves, the one power piston itself acting as the inlet valve, and the second power piston acting as the outlet valve.

The casting of the cylinder is of the very simplest type, consisting of two single-walled U tubes placed end to end, the inlet and the exhaust ports being about the joint; flanges on the cylinders—set back somewhat from this juncture—hold in between them the exhaust and inlet boxes. The absence of joints and cavities in the combustion chamber reduces the risks of pre-ignition, and improves the efficiency of scavenging. The piston operating the inlet port has, of course, a slight lead on the piston operating the exhaust port, so that the latter is closed at the time of explosion. Every stroke is a driving stroke.

The duplex cylinder is placed in a simple tank of water for cooling, and it is possible to run the engine with this water boiling. With this type of engine it is quite practicable to have a single unit of 10,000 brake-horse-power.

GNOME ROTARY ENGINE

The advent of the Gnome Rotary Engine, in 1909, marked a revolution in aviation. The novelty of the invention consisted in making the cylinders themselves rotate around the crank-shaft. Instead of the orthodox revolving crank-shaft and fixed cylinders, there was a fixed crank-shaft and revolving cylinders, the object being to keep them cool.

The inventor was Mons. Seguin (France), and so revolutionary was the idea that it met with very severe criticism at first. Even when it had proved its remarkable staying powers, an expert said (1912): "If I were asked to give my opinion of the Gnome motor in as few words as possible, I should say that it was *theoretically* one of the worst-designed motors imaginable, and *practically* the most reliable aeroplane engine I know of. I should have to add as a qualification that I assume it receives the constant attention of expert mechanics." (Earl L. Ovington. *Scientific American*, cvii., No. 11.)

The object in the Gnome motor is to obtain as much power as possible with a minimum of weight; the real purpose being a fast flyer for exhibition purposes, not for long distance travel. Every part of the engine is cut from the solid metal, or from a forging; no part is cast. The metal from which the cylinder is cut weighs 81 lb., but the finished cylinder which is cut out of this weighs only 4.5 lb. The exhaust valve screws into the end of the cylinder, and is arranged so that it may be removed in one piece with its seat, as it requires constant grinding. Indeed, after about fifteen hours running, the motor is taken to pieces and thoroughly overhauled, while the valves are re-ground and re-timed, and new valve-springs inserted.

The bore of the cylinder has a mirror-like surface, and there are no piston-rings, each cylinder merely having an 'obturateur,' which is a simple ring of thin sheet bronze. The crank case is cut from a solid forging, weighing in the rough 116 lb., while all that remains in the finished crank-case is 13.5 lb. It seems strange that of the total weight of metal prepared for the cylinder and crank-case, less than 10 percent remains in the finished motor, 90 percent being waste shavings. The object of the Gnome's revolving cylinders is, as already stated, to keep them cool, water-cooling not being convenient in an aeroplane.

SUN-POWER PLANT

One of the most interesting of the practical attempts which have been made to utilize the radiant energy of the sun, is that which was invented by Frank Shuman, of Philadelphia, a few years ago.

Instead of focusing the rays of the sun by means of lenses and mirrors, and using the concentrated rays to heat a boiler, Shuman collects the radiations falling upon a very large surface area. A large plant which was to be shipped for use in Egypt was fitted up in Philadelphia for experimental work, prior to shipment. It consisted of twenty-six long troughs, made of wood, each containing a flat metal honeycomb water vessel, covered with two layers of glass, having a one-inch air space between them. In order to prevent loss of heat through the box, the under surface was insulated by a two-inch layer of granulated cork and two layers of waterproof card-board.

In order to collect as much radiation as possible, plane mirrors were mounted on two sides of the boxes, and the rays were reflected upon the surface of the water vessel. By this means, an absorptive area of over ten thousand feet was secured. The boxes were supported on stands about thirty inches off the ground, and were placed with their surfaces perpendicular to the sun at the meridian, the position being readjusted about every three hours.

The water vessels were connected at one end by a feed-pipe from the water supply, and at the other end to a steam-pipe. The branch pipes from the various units led into a main steam-pipe which conveyed the steam to the engine.

The prime-mover is specially designed for low pressure, and has a condenser and other usual auxiliaries. The water from the condenser is pumped back into the absorber, thus making a continuous circuit, the only water loss being accidental leakage.

During the experiments in Philadelphia, the plant was used to pump 3000 gallons of water per minute, to a height of thirty-three feet. The experience gained by these trials led to a number of important alterations being made before the plant was shipped to Egypt. Instead of using plane mirrors to reflect the rays through the glass tops of the water vessels, rectangular zinc troughs were placed in the focus of long parabolic mirrors, each about 200 feet in length. These parabolic mirrors of silvered glass were mounted in arc-shaped frames, which could be turned so as to face the sun at all times. This alteration of position was accomplished automatically, the power being obtained from the engine itself, which is provided with a pair of friction pulleys under the control of a special thermostatic regulator.

When the plant was erected in Egypt, the temperature of the tank reached a point so near the boiling-point of zinc, that the metal could not withstand the heat. But the results obtained were so encouraging that the inventor decided to replace the zinc troughs by steel ones. It will be understood that there is only a film of water kept passing through the troughs. The inventor claims that the cost of running his Sun-power plant is only one-third of that from an ordinary coal-heated steam plant.

It is interesting to note in connection with this invention that Sir J. J. Thomson, in his presidential address to the British Association in 1909, said: "How great is the supply *(of energy)* the sun lavishes upon us becomes clear when we consider that the heat received by the earth under a high sun and a clear sky is equivalent, according to the measurements of Langley, to about 7000 horse-power per acre. Though our engineers have not yet discovered how to utilize this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water-power inadequate, it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about, our centres of industrial activity may perhaps be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams."

CHAPTER V

MECHANICAL INVENTIONS

THE MONOTYPE MACHINE—OFFSET PRESS—AUTOMATIC PRESS—ROTOGRAVURE MACHINE—RE-SHUTTLING LOOMS—AUTOMATIC HIDE-MEASURING MACHINE—BOTTLE-HANDLING MACHINE—MATCH-MAKING MACHINE—ENAMELED-BRICK MACHINE—REINFORCED CONCRETE POLES—CHICKEN FEEDING MACHINE—CIGAR-SMOKING MACHINE—PILL MAKING MACHINE.

THE MONOTYPE MACHINE

To watch a Monotype operator at work does not give one any idea of what he is doing, except that he is operating an enlarged type-writer with 276 keys, and that he is producing a perforated ribbon about four inches wide, which, so far as its appearance goes, might be for some form of piano-player.

The automatic machine, which is to be controlled by this perforated ribbon, is practically a type-foundry, not only capable of casting any letter at will, but able to place the types in position to form words, sentences, and paragraphs, until a whole page or column is quite complete.

While the Monotype consists of two separate machines: (1) the keyboard with punches for preparing the perforated paper, and (2) the casting machine, and while these take the place of the compositor and the type-founder, it would not be correct to describe the one machine as the compositor and the other as the type-founder. The ordinary hand compositor has in the first place to make up his mind what letter he requires, select it from his case, and then place it in his compositor's stick, and so on. The Monotype keyboard, which prepares the perforated paper, is merely equivalent to the man determining which types he requires to form the words and sentences which he desires to set up. In other words, the prepared ribbon is equivalent to the brain of the compositor; it is to control the actual operations which take place in the casting-machine. The prepared paper-ribbon will be understood more easily when we know what it is to control.

The casting-machine has a mould into which a pressure-pump forces up molten type metal. This mould is open at the top, and the metal would overflow unless some lid or cover were clamped down upon it. The cover for the mould is the matrix forming a letter of the alphabet, and when this is clamped automatically upon the open end of the mould, a type is cast. This type is almost instantaneously cooled by cold water circulating around the mould. The mould is fixed in one position, but the matrix-case containing the matrices for the different letters is movable, and, according to the letter required, can be brought at will into position over the mould.

Not only must there be matrices for the twenty-six letters of the alphabet, there must be a complete alphabet of 'lower case' (small letters), small capitals, capitals, italics, italic capitals, punctuation marks, brackets, fractions, figures, and so on. In all there are 225 different matrices, arranged in fifteen rows of fifteen matrices in each, the whole occupying a space of three square inches. Of the 225 matrices, 221 are characters and four are characterless for spaces.

When the desired matrix is to be brought over the mould and clamped down to complete the mould, it is necessary that the matrix-case should be moved automatically a definite distance from right to left, and from back to front. Combinations of these two movements will bring any desired matrix over the mould. To control the positions of the matrix-case it will be necessary to have fourteen stops in the direction from right to left, and fourteen stops in the direction of front to back; the fifteenth position each way, being the limit of the movement, will not require a control stop. And so we find in the machine two sets of small pistons, there being fourteen pistons in each set. Each of these pistons is connected to a separate tube, through which compressed air may be blown in order to force the piston upwards. When air is admitted to a tube, the piston rises and arrests the travel of a rod attached to the matrix-case. One of these sets of rods controls the extent of the right-to-left movement, while the other set controls the movement from back to front. It will be apparent that the perforations of the paper-ribbon are to control the actions of these pistons, by permitting compressed air to pass through into two of the tubes. In so doing the position of the matrix-case is determined, or, in other words, the matrix required for the casting of the desired type is brought over the mould. The striking of the keys on the keyboard thus controls the casting-machine, the medium of communication being the perforated ribbon.

The casting-machine which we have built up in our imagination has only 28 air-tubes and pistons, whereas we find 31 tubes and pistons in the actual machine. The three additional tubes operate small pistons at the centre of the machine, and these control the actions of certain rods, one piston causing the caster to produce the characterless space type, the other two regulating the size of the spaces, and putting the galley motion in action, as will be explained later.

So far we have followed the general principle of the casting, but the types arc all made in the one mould, and this might seem to necessitate the shanks of the types being all the same thickness. If such were the case the letter 'i' would occupy the same space as the letter 'm,' and the resultant printing would be similar to what we get from a type-writer, producing the letter 'i' surrounded by too much empty space, while two 'm's' when placed together in a word always seem overcrowded.

This difficulty is overcome in the casting-machine by the width of the mould being adjusted or 'justified' automatically for each letter. This is done by the movement of a wedge. The entrance of the thick end of the wedge will make the mould narrow enough to suit the letter 'i.' When the wedge is partly withdrawn the mould will increase in width suitable for the letter 'o,' and so on till the small end of the wedge leaves the mould at its widest for the capital letter 'W.'

We have seen how the matrix-case is brought into position so that the desired matrix is over the top of the mould. The matrix is held down on to the mould by means of a conical-pointed steel pin, which descends into a cone-hole on the free end of each matrix. At each stroke of the machine this steel pin descends and engages with whichever matrix has been brought beneath it, and thus clamps it securely to the top of the mould. At the same time the wedge has adjusted the width of the mould opening, and the pump forces the molten metal into the mould against the matrix.

The type-metal is composed of certain proportions of tin, antimony, and lead, and is kept in a molten condition (about 680°) by means of two Bunsen burners. The well and delivery channel of the high-pressure pump are immersed in the molten metal. A device is provided for cutting off the jet of metal at the foot of the type, and then conveying the new type to a channel into which it is ejected. Each succeeding type pushes the others onward in this channel leading to the galley, until all the type and spaces required to fill a line are complete.

It is evident that the length of the line must be controlled by the perforations of the paper-ribbon, otherwise the casting-machine would continue making an endless regiment of type. When the line has been completed, type by type, it is brought down to the galley by means of special air-tubes and pistons, which operate the mechanism for this purpose. The line is pushed into the galley, passing under a gate which descends as soon as delivery is completed, thus shutting the line of type in the galley, the mechanism being restored to its original position as soon as this work is finished. Each succeeding line pushes the previously cast lines forward in the galley, until the galley (representing a page or a column) is full. It is then removed and an empty galley is placed in position.

We have left out of account the size of the spaces between the words. The hand compositor adjusts his spaces so that the type exactly fills his 'stick,' but how is the Mono-type to do this? The operator at the keyboard, which prepares the perforated paper-ribbon, will, of course, depress a space-key between each word, and the machine will ring a warning-bell before it has reached the very end of the line, but what is he to do with the remaining space? It is only the space of a few letters, but it would look very ugly to leave a series of ragged spaces at the ends of the lines. The remaining space must be distributed over the spaces between the words. This is what is called 'justification' of the line.

When the operator has completed the line as far as he can go, he depresses a special 'justifying' key, which causes a drum or cylinder to revolve a certain distance, according to the space used by the letters and spaces already included in the line. A small indicator points to two figures upon the justification scale-drum and indicates to the operator which two of a special set of thirty keys he must depress. The two holes thus punched at the end of each line are the first to operate in the control of the casting-machine, as the paper-ribbon is fed in backwards. These two perforations control the die-case and the justification wedges which determine the size of the spaces to be cast between the words.

It will be understood that when the key-board operator has depressed a key and thus made two perforations simultaneously, the paper-ribbon moves forward one-eighth of an inch. Therefore when the prepared paper-ribbon moves forward (or, rather, backwards) through the casting-machine, only two holes will be presented at each stroke, thus casting one letter at a time.

When the proof-reader corrects a printed sheet produced by the type, the corrections which he has marked are made just as easily as in hand-set type, for each letter and space is separate.

The keyboard operator can prepare his perforated paper-ribbon in about one-seventh of the time that the hand compositor can set his type, while the automatic caster goes steadily on casting and setting at the rate of 7000 to 10,000 types per hour. This means that while one hand compositor working alone could set one and a half columns of a news-paper in a day, the Monotype could set about ten columns in the same time. The Monotype caster will, of course, require an attendant, but one man may conveniently watch two casting machines.

In order to appreciate the ingenuity of the invention it is worth while summing up the actions of the caster in making a single type.

1. The perforated paper-ribbon is fed forward one-eighth of an inch. This is accomplished by means of special perforations made in the edges of the paper before it is used in the keyboard machine.
2. The die-case is moved into the proper position to bring the desired matrix over the mould.
3. The matrix is centred by the coning-pin
4. The mould-blade opens out the amount necessary to enable the particular type to be cast its proper width set-wise.
5. The matrix is clamped to the top of the mould.
6. The pump injects the molten metal and the type is cast.
7. The matrix is lifted off the mould.
8. The mould jet-blade guillotines the jet off the foot of the type.
9. The carrier throws the jet back into the casting-pot.
10. The type is ejected into the carrier.
11. The type is carried away from the mould.
12. The type is pushed out of the carrier into the channel leading to the galley.

We may think of the separate actions of pistons, rods, etc., required to bring about each of these twelve distinct operations, and then picture all this being done by the casting-machine, not only once in every second of time, but nearly three times per second.

As the casting-machine produces a new type for each letter, there are no printer' s errors due to wrongly distributed type, and there are no badly-formed letters due to worn type. However, the many commercial advantages claimed for this ingenious invention do not come within our present interests.

OFFSET PRINTING PRESS

The 'Offset Press' in lithography is an adaptation of a press designed for printing designs on tin boxes. The general principle is that a greasy image is prepared by drawing, or by photography, on a thin sheet of zinc, which has been prepared previously with a grained surface so that it will retain moisture, just as is done by the ordinary lithographic stone.

This zinc plate is fixed upon a cylinder in the printing press, which has damping and inking rollers as usual. The new feature is the method of impression, which is not taken direct on to the paper. The zinc plate prints on to the surface of a rubber-covered cylinder, and the paper is fed in between this and another rubber-covered cylinder, the impression being transferred to the paper by the inked rubber surface. This method of printing from a rubber-covered cylinder does away with the necessity of using a highly-polished paper for lithographic printing; practically no paper is too rough to print even half-tone pictures.

As the motion is rotary, instead of reciprocating, the speed can be increased enormously, at the same time dispensing with the bang and clatter of the ordinary litho-press. The speed has been increased still further by making the machine entirely automatic, in the following manner.

AUTOMATIC PRINTING PRESS

Until the invention of the Offset Press, it was considered necessary to have a to-and-fro motion when printing individual sheets of paper. The rotary machines of the nineteenth century were of use only when printing a continuous reel of paper.

The Harris Automatic Press not only takes entire charge of the feeding of individual sheets of paper, but it will stop printing the moment the stock of paper is exhausted, and it will refuse to pass two sheets at a time. When once set up ready for printing, any intelligent boy may attend to the machine, which is quite capable of taking care of itself so long as it has a stock of paper within its reach.

The automatic throw-off comes into action before the printing cylinder comes to the point of applying the impression. If no sheet of paper intervened between the printing and the impression cylinder, the latter would receive the ink. This is obviated by the impression throw-off placing the cylinders out of contact. It would not be sufficient merely to switch off the driving power, for the rotary machine has some momentum, causing the cylinders to rotate for several revolutions. If the machine should feed forward accidentally two sheets of paper sticking together, the throw-off comes into action in a very simple manner. A micrometer gauge, which is set to the thickness of the paper being printed, prevents the two sheets from passing to the cylinders, and the absence of paper calls the throw-off into action.

The printing type must, of course, fit around the paper cylinder, and this is done usually by means of stereotype and electrotype plates. These may be cast or made in the flat and then curved to fit the cylinder by means of a bending machine.

These automatic presses are not confined to simple work, but will print in one or two colours at a time. They will undertake all the work required in making manifold impression books, numbering, perforating, scoring or slitting, and cross-perforating, all at one operation. This is quite impossible on flat-bed presses.

ROTOGRAVURE PRINTING

The invention of the half-tone process, and even the three-colour process of printing, belong to last century. The printing from these is dependent upon raised dots taking the ink and impressing it upon a smooth-faced paper. If illustrations are required to be printed along with the text (except by the off-set press), it is necessary to have the whole book printed upon a glossy paper, as the tiny dots cannot print upon a rough surface. When illustrations are wanted on rough paper, they are made by the photogravure process. In this case the ink is not received in a layer of uniform thickness on raised dots as with the half-tone block, but is received in depressions of various depths on the surface of the printing-plate. These depressions or etchings depend upon the various depths of shadow required in the impression.

We are not concerned with the preparation of these printing surfaces, as they are not of this century, but until recently the printing of photogravures was done by hand-presses, the printer covering the plate with ink, scraping off the surface ink and leaving the sunken images filled with ink, then pressing the rough paper firmly against this inked plate so that the ink is transferred from the depressions to the paper. The metal plate is really a mould, and the illustration is a casting of ink obtained from the mould. Apart from one firm who had a secret process, all photogravure printing was necessarily slow and expensive.

The action of the 'Rotogravure' quick-printing machine is very similar to that of an ordinary calico or silk printing machine, in which the colour-box puts the colouring material upon the engraved roller to fill the hollows, and then the excess is scraped off by a long flexible knife, leaving the surface perfectly clean. The Rotogravure machine works in the same fashion, but with printing ink, and the machine may be coupled up to an ordinary newspaper machine, so that the paper runs through both machines unbroken. Some of the Continental daily newspapers are now being illustrated in this fashion. The machine may be used by itself for the production of fine art illustrations.

The machine prints on an endless web of paper, fed from a reel. After leaving the reel, the paper passes over the first engraved roller, and then over a steam-drum which dries the ink. Then the paper passes on to the second engraved roller. The paper is pressed against the etched copper roller, by means of a rubber-surfaced drum, and may be printed on both sides on its way through the machine. The second printing is dried by means of an electric radiator and blowers, after which the paper passes through rotary knives which divide the paper into sheets. The product of the machine is 6000 copies of each subject of an eight-page sheet in an hour-48,000 individual illustrations per hour.

In connection with rapid printing, it is interesting to note that the Public Printer, of the United States Government Printery, invented a machine, in 1910, capable of printing more than half a million post cards per hour, the actual speed being 144 per second. The cards are cut automatically by the machine, and then dropped in eight stacks, until there are twenty-five post cards in each pile. The eight stacks then move forward and are bound automatically with a paper band, and the finished packets are dropped into a box.

RE-SHUTTLING LOOMS

The power-loom, invented in 1785, had become during the nineteenth century so reliable an automaton, that one might have supposed no further important invention could be made in connection with it.

The power-loom not only replaced the movements of the hand-loom weaver's legs and arms by revolving tappets or eccentrics, but the loom would stop automatically when the weft (shuttle thread) became broken or was exhausted. It stopped also when a shuttle stuck in its way across the loom. The girl 'weaver' was in reality an attendant to keep the machine to its work. One weaver could attend to several looms, as she had only to put in a full shuttle when the loom stopped for lack of thread, and then restart the loom. The loom required no attention in this direction until it stopped automatically, but the weaver had to keep a lookout for any broken warp threads, and stop the loom while she mended these. It might seem that these duties would always require the human operator, but recent inventions have put all these responsibilities on the loom itself, with the exception of the actual mending of the warp ends.

One of these modern looms will not only stop when its weft thread is broken or exhausted, but it will throw out the empty shuttle, replace it with a full one, and restart the loom, the whole operation taking only a few seconds. Not only is this loons quite independent of the weaver watching its shuttles, but it must also look after its own warp, in so far that it must not go on weaving while any warp threads remain broken. The principal duty of the twentieth century weaver is to mend the broken warp ends when the loom stops for that purpose. One of her minor duties is to see that the loom has a store of full shuttles in its magazine.

We picture the loom at work, throwing its shuttle from side to side; it keeps running so long as the weft and the warp are perfect. The moment the weft thread breaks, the loom stops, its re-shuttling apparatus is called into play, and off it goes again with a full shuttle. Even more interesting is the means by which the loom can tell that its shuttle is nearing a state of emptiness, so that the shuttle may be changed before the loose end is thrown and woven into the cloth. This is accomplished by a weft-feeler motion.

As already mentioned, the means of stopping the loom automatically when a weft thread breaks is an old invention. In this case the weft thread, while being tightly stretched across the web by the shuttle, serves to hold out of action a trigger which a lever is seeking to pull, at each stroke of the lay (the going part which carries the reed and the shuttle). So long as the weft is present to keep this light trigger out of the way, the loom runs on, but when the weft is absent or broken, the trigger is pulled by the moving lever and the handle of the loom is thrown to the 'off' position, bringing the driving belt on to the loose pulley. In the new loom this action not only stops the loom but also sets the re-shuttling apparatus in motion. In addition to this, there is now the weft-feeler motion, to which reference has already been made.

This weft-feeler motion consists of a simple combination of levers, culminating at the one end in a flat metal finger which feels the yarn in the shuttle at each forward stroke of the lay. The yarn is wound upon a wooden pirn which has an open slot cut through it, while the shuttle has a corresponding slot cut in its side. If the pirn were empty, the metal finger would enter the slot at each stroke, but the yarn, being wound upon the pirn, covers the slot and prevents the metal finger entering it, the feeler being pushed back against a light spring. At each backward push, the feeler lifts a light trigger out of the way of a moving lever which is seeking to engage with it. When only a few turns of the weft remain upon the pirn, the feeler does succeed in entering the slot, and the feeler failing to push the trigger out of the way of the moving lever, the loom is stopped automatically. At the same moment the re-shuttling motion is called into play, exchanging the almost empty shuttle for a full one.

As the re-shuttling motion is to be operated while the loom is at rest, it is necessary to drive its mechanism from the loose pulley, on which the loom belt runs while the loom is off. For this purpose the loose pulley carries with it on the crank-shaft a sleeve with a toothed wheel, which by intermediate gearing carries the power to the re-shuttling apparatus. In some of the latest models, the clutch for this motion runs in an enclosed oil bath, and receives its power by means of a chain driven from the loose pulley. This clutch causes the tappets or eccentrics to make one revolution, and operate the levers of the re-shuttling motion, and then disengage the clutch by restarting the loom.

There are four of these tappets, the relative positions of which are fixed, so that each comes into play at the required time. The first operation necessary is to open the shuttle box to permit of the empty shuttle being pushed out. The box is opened by raising its front, so that the duty of the first tappet is a simple one: a vertical rod is pushed upwards and the box front, being attached to the upper end of this rod, slides upwards, leaving an open space opposite the shuttle. As soon as the box is completely open, the second tappet comes into play, its duty being to operate the pushing out lever.

A motion of this kind is better not to be a positive motion, as it would not do to force the shuttle out against any obstruction. To prevent any such accident, the whorl (friction roller) of the operating lever rests upon the highest point of the pushing tappet and is held there against the pulp of a strong spiral spring. When the tappet is revolved, the lever is pulled by the spring, and the pushing out lever ejects the empty shuttle through the open front of the shuttle box. Should there be any obstruction, the spiral spring would not force the shuttle unduly, the energy would be dissipated in the spiral spring. As soon as the shuttle is ejected, the pushing lever returns to its normal position, leaving the box empty.

Meantime the third tappet has commenced to fulfil its duty of inserting a full shuttle. There is a magazine of full shuttles lying one on the top of the other, the bottom one resting upon two metal fingers. When these fingers are drawn away from beneath the magazine, a metal shelf or tray takes up its position, so that when the supporting fingers have been withdrawn, the pile of shuttles falls on to this tray, but only the bottom shuttle is free to be drawn away by the supporting tray, when it moves towards the shuttle box of the loom. As the tray moves away, the two metal fingers take up their normal position again and support the remaining pile of shuttles in the magazine. When the full shuttle has been carried forward and placed in the shuttle box, the carrier or tray returns to its normal position just in front of the magazine. While these different operations have been proceeding, the first tappet has continued to keep the shuttle box open, but now this tappet allows the vertical rod to drop down, carrying the box front with it. The loom is ready for weaving once more. A fourth tappet, with a very sudden rise upon it, now comes into action, and this pushes the handle of the loom to the 'on' position, causing the loom belt to be pushed over from the loose to the fast pulley.

But suppose the weaver has omitted to keep the magazine filled with shuttles and only an empty tray reaches the shuttle box; in this case the loom will refuse to start. The same holds good if for any reason the full shuttle fails to enter the box properly. As one gentleman, who had an intimate knowledge of looms, remarked, 'This is the loom with the brains.' And yet the object is attained in a very simple manner. So long as there is a shuttle in proper position in the shuttle box, the shuttle presses against a swell spring which keeps a trigger out of the way of a catching lever. But if there is no shuttle in position in the box, this swell spring gets forward and allows the trigger to engage with the catching lever, and this in turn prevents the starting lever pushing the loom handle over to the 'on' position.

As the re-shuttling loom is able to take so much responsibility upon itself, it requires very little attention from the weaver, who may take charge of as many as twenty looms. She cannot undertake to look out for broken warp ends in all these, so it becomes necessary that the loom accepts this duty also. There are many mechanical warp-stop motions. In one of the latest inventions, each warp thread supports a very light and thin piece of flat steel, about 31 inches in length. These are so light that there is very little friction on the warp threads upon which they hang stride-legs. So long as all the warp threads are whole, all the units of this regiment of 'droppers' are held up in position, but the moment any one thread breaks its dropper falls, and its lower end engages with a rocking lever which is making a to and fro motion at each stroke of the loom. So long as this to and fro motion is free, the loom runs on, but the moment any dropper obstructs the rocking motion the loom is stopped automatically, the loom handle being knocked over to the 'off' position. The loom having come to a standstill, the weaver can see at a glance along the regiment of droppers which particular warp end has broken.

There is another automatic loom which, instead of changing an empty shuttle for a full one, throws out the empty pirn and replaces it by a full one, while the shuttle remains in the loom, and while the loom continues working at full pace. The claims as to merits and demerits made by the rival inventors do not concern us here; both inventions are most ingenious.

It might seem a practical impossibility to change the pirn in the shuttle of a loom while making, say, 180 picks per minute. We may picture the loom throwing the shuttle across the web three times in every second. The shuttle has only one-third part of a second in which to leave the one box, cross the loom, and take up its position in the other box. It has only time to be shot into and out of the box, and yet during the fraction of a second in which it is at rest, the change of pirn must take place.

Instead of a magazine of shuttles we have in the present invention a 'battery' of full pirns. These are held horizontally between two large metal flanges, and when the full charge of twenty-five pirns is in position, they form as it were the circumference of a drum. This battery of pirns is fixed at one side of the loom immediately in front of the shuttle box. The position of the battery is such that when the forward stroke of the lay brings the shuttle box beneath the battery, a full pirn is held immediately over the empty pirn in the shuttle. When the re-filling motion is brought into play by failure of the weft (by means similar to that already described), a pushing lever or 'transfer hammer' forces a full pirn out of the battery and into the shuttle exactly on the top of the empty pirn. The blow and length of stroke are just sufficient to knock the empty pirn out through the bottom of the shuttle box and to cause the full pirn to click into position in the shuttle. In these shuttles the pirns are merely held in position by flat metal springs pressing on a special circular base on each pirn.

Taking a full shuttle in one's hands, by way of experiment, and placing a second pirn over the one already in the shuttle, it is possible with a sudden downward thrust of the upper pirn to force the lower pirn out through the bottom of the shuttle while the upper one clicks into its place; the loom does the same thing automatically while in motion. Of course the weaver has to charge the battery with full pirns, but this she can do in two to three minutes, and the loom when charged can run for two and a half hours without any further attention so far as the weft is concerned.

As evidence of the reliability of such automatic mechanism it may be mentioned that while the weavers are absent during meal hours the looms continue weaving on their own account. In many factories, with the ordinary looms, it is a source of worry to see that all weavers are clear of the looms during meal hours, for no worker may mend a broken end or replace an empty shuttle at these times. With these automatic looms the weavers may leave them at work when they go home for breakfast, and about seventy percent of the looms will be found to be at work on the weaver's return an hour later. Those looms that have stopped will be waiting for some warp threads to be mended.

The present-day loom is an automaton performing actions which once required human brains and hands to perform. What the position of the weaving loom will be by the end of the twentieth century it is impossible to foresee.

AUTOMATIC HIDE-MEASURING MACHINE

The buyers and sellers of hides in the great boot-making industry have appreciated the invention of a mechanical means of measuring hides. To buy and sell by weight was not a satisfactory method, as the real value depends largely on the surface area. Until recently the buyer had to depend upon his own judgment as to the relative value of the hides, so far as the area measurement was concerned.

The automatic hide-measurer will calculate the exact measurement in square inches of a hundred hides before an expert civil engineer could have surveyed half a dozen of them. Not only does this automaton add together the square inches contained in the back, the forelegs, the neck, the belly, and the hind-legs, but if there are any holes it does not include the missing portion in the total measurement.

The general appearance is that of a long mangling machine. The attendant places a hide on the table and feeds it in between two long rollers. The under one is a continuous cylinder, but the upper one is composed of a regiment of individual wheels, set close together. The under roller is driven by power, and as it revolves it conveys motion to each of the long row of wheels resting upon it; they revolve because of their contact with the under roller. Each wheel has an axle of its own which is supported by a forked lever, and the balance is such that a weight keeps the wheel pressing against the under roller. But anything passed through between the under roller and the wheel lifts the wheel and its supporting lever upward. Each wheel has on one end of its axle a toothed pinion, which revolves freely when the wheel is down upon the bare under roller, but when the wheel is raised, this pinion engages its teeth with the teeth of a quadrant suspended above it. So long as the wheel is kept up by the hide, this quadrant is moved forward; it is practically the sector of what would be a large toothed wheel. If the pinion and a large wheel were engaging for long, there would be a complete revolution of both. The quadrant, however, is never required to describe more than a small arc of the circle. When the quadrant moves, it pulls down one part of an arrangement of multiple levers. Each wheel and quadrant can pull independently at these levers, and the total haulage is added together in the movement of one long lever which is geared to the indicator of a large dial.

If all the wheels were to move their quadrants a certain very short distance, the indicator would point to one square inch. If only half the number of quadrants were moved, they would require to travel twice as far to indicate a square inch, and so on.

Let us suppose that an irregularly shaped hide is being run through between the roller and the wheels. The attendant may place it broadwise or lengthwise, it will make no difference. Only when a wheel is raised by the hide beneath it will it operate the multiplied lever arrangement. While a foreleg passes under one of the wheels it registers, then it disengages from its quadrant while no leather passes, but registers again the moment a bit of the irregularly shaped belly passes beneath it. When a hole passes beneath a wheel, it leaves the registering alone until it is raised once more by the hide.

While a wheel disengages with its quadrant it must retain its pull upon the multiple levers, or the measurement would not be cumulative, and the indicator would fall to zero when the hide had passed. As a quadrant is stepped forward, a pawl and ratchet retains it at each step, so that when the hide has passed out from the rollers, the quadrants all remain in the positions to which they have been moved, and the indicator stands opposite the figure on the dial which represents the total area of the hide. The attendant chalks a note of the square inches upon the back of the hide, pulls a lever which releases the quadrants, and with them the whole multiple lever arrangement, whereupon the machine is back to zero, and ready for the next hide. Some machines of this class can measure from 3000 to 4000 skins per working day.

SUBINDUSTRIAL INVENTIONS

Many volumes might be written upon the subject of new Industrial Inventions, but to describe many pieces of complicated machinery would require a multitude of diagrams and details which would not be of general interest. It may be of interest to note a few of the legion of automata which are cropping up almost daily.

One combined machine handles bottles in quite a remarkable fashion, taking in the plain bottles (already filled and corked) at one end of the machine and handing them out at the other end capsuled, tin-foiled, labeled, wrapped in tissue, and counted. The first part of the machine attends to the capsuling and the application of a piece of tinfoil around the neck. Then the bottles pass on automatically to the second part of the machine which labels them, and if desired, it will apply a neck label, a body label, and a duty strip. The final section of the machine not only wraps the bottle in a tissue paper, twisting it around the neck, but will also print the label if desired. It also registers the number of bottles which it handles.

Another ingenious machine accepts solid blocks of pine-wood at one end and at the other end fills empty boxes with finished matches, closes the boxes, and seals them up in packets, each containing one dozen boxes. This machine first cuts forty-eight match sticks at a single stroke, then places the sticks in rows of holes in a travelling band, and as this moves forward it dips the free ends of the matches into the igniting composition. The endless band carries them to and fro in the machine until they are dry, and then empties the finished matches into travelling receptacles, each holding sufficient matches to fill one box. These receptacles are brought in turn opposite the open boxes, and when the matches have been transferred to the boxes they are closed automatically. The boxes then move forward to a machine which picks them up, a dozen at a time, places them on a printed wrapper, and pastes and folds this round them in so human a fashion as to be almost uncanny. One of these ingenious match-making machines turns out 144,000 boxes of matches per day.

Another machine of gigantic proportions accepts the raw materials for the manufacture of concrete and enamel, and it makes automatically immense quantities of concrete bricks, each with an enameled surface. The machine is fed at one point with the concrete materials, and at another with the enameling material. The concrete is received in a series of hoppers which weigh out the exact quantity required for a single brick or tile. Each hopper then pours its contents into a mould. The enameling material is dealt with in a somewhat similar fashion, and is added to these moulds when they reach that section of the machine. The materials are then united with a pressure of 3,200,000 pounds, which brings about a perfect cohesion, after which the moulds eject the completed bricks, at a rate of almost 700 per minute.

A few years ago a Swiss engineer invented a machine for making reinforced concrete poles, dispensing with the setting of the material in moulds. The concrete mixture is used almost dry and requires considerable pressure to cause it to cohere. The mixture is carried in a hopper over the pole-making machine, in which is held a long core of sheet iron, around which is the metal skeleton for the reinforcement. This consists of steel wires or rods of small section held in position by a series of constructional gauge rings.

The concrete mixture is fed on to a conveyer band, on which lies a webbing or bandage. As the machine wraps this webbing of concrete around the core it applies a pressure of 5000 pounds. The hopper of the machine and the bandaging apparatus slide along the core, wrapping the bandage over the core in a spiral form, and at the same time removing the gauge rings, and applying, as a further reinforcement, a wire in the form of a long spiral embedded in the pole. When the pole has set, the sheet iron core can be reduced in diameter by means of a screw, so that the core may be withdrawn. Finally the bandage of webbing is removed.

Among the multitude of inventions is a chicken-feeding machine (forcible feeding), by means of which one man may feed 300 chickens twice a day, with a patent liquid food. A suction pump, worked by a foot-pedal, forces the food through a tube (ten inches long) through the chicken's mouth into its crop. When the crop is full the flow of food stops instantly, and no possible injury can be done to the chicken.

Another invention is a machine for smoking cigars—not that there is any scarcity of smokers, but in order to test the filler, binder, and wrapper which go to make up a cigar. The cigars are held in the ends of glass tubes, which are connected to a series of flasks. An aspirator and siphon, by means of moving water, suck in the smoke at regular intervals, about the rate at which a man smokes. Comparisons are made in this way between different deliveries of tobacco and different makes of cigars.

Another machine manufactures one million pills per day of ten hours. There are really two machines combined, a ball-making machine, and a pill-machine. The ingredients are mixed in a hopper, which presses the mixture through a nozzle, where it is cut into lengths. As these fall into a guide-receiver they are subjected to a shower of sifted flour and then placed on a rolling belt. The balls formed by this means, are then conveyed automatically by a lift to the pill-machine, and dropped into the receiving funnel of the 'automata.' Here the ball becomes elongated into a strip or pipe, by being rolled many times about its own diameter. It then drops on to revolving cutters, where it is instantly divided into pieces of accurate weight by measurement. Finally these individual pieces fall on to a chute, which conveys them to the pill-rounding belts. When once drawn in between the rolling belts, they advance, many hundreds side by side, and go whirling through the 'automatic globular perfects.' They pass at last through a separator, by which the good pills are retained and the tailings rejected.

CHAPTER VI

GYROSTATIC INVENTIONS

THE GYRO-COMPASS—PREVENTION OF SHIPS ROLLING BRENNAN MONO-RAIL CAR

THE GYRO-COMPASS

The invention of a gyrostatic compass came as a surprise to most people, and yet the fact that a gyrostat could act in this way had been known for two generations. So long ago as 1852, the French philosopher, Foucault, demonstrated that any gyrostat, free to be turned in two directions only, will tend to set itself with its axis of rotation parallel to the axis of the earth, by reason of the relative rotations of the two bodies. He pointed out that this law would hold good for a gyrostat (with two degrees of freedom) at any place on the earth's surface other than the two poles.

The average man probably knows little more of a gyrostat than can be observed by handling one of those simple gyrostatic tops, such as are sold as toys at exhibitions. Even if one sets such a gyrostat spinning, and holds it with the axle, say, in a vertical position, one may feel that the gyrostat resists any attempt to move the axle away from its vertical position. Better still for our present purpose if the spinning gyrostat is held with its axle in a horizontal position, whereupon the same resistance is apparent if we seek to alter the direction of the axle.

A gyrostat may he given three degrees of freedom. For instance, we might suspend the toy gyrostat by a piece of string attached to its equator ring. If care is taken to balance the gyrostat in this position, with its axle horizontal, it is quite apparent that it remains in a definite position and that it resists any change in the direction of its axle. In whatever direction we place its plane of rotation, it will remain in that position in space while the earth turns round beneath it. This was the first law which Foucault laid down concerning gyrostats. He pointed out that a gyrostat, if free to turn in all three directions, would serve in the same manner as his pendulum to demonstrate the rotation of the earth; the gyrostat would take up a fixed position in space, and we should see the earth turn round beneath it.

Dr Anschutz, of Germany, began experiments in 1900 with a gyrostat having three degrees of freedom. Of course, if such a gyrostat, say on board ship, were placed with its axle pointing north and south, it would remain in that position, no matter how much the ship turned about, but it would possess no directive force. If the motor driving it had to be stopped for any reason, the direction would be lost. If while it was spinning any one happened by contact to alter its direction, it would remain pointing in some false direction.

Anschutz had no intention of using such an arrangement in place of the magnetic compass, but merely to get fixed lines in space, for obtaining bearings or maintaining a course already definitely known. However, he found it practically impossible to construct a gyrostat having its centre of gravity and centre of suspension absolutely coincident.

In 1906 Anschutz turned his attention to a gyrostat having only two degrees of freedom. At first he combined this gyrostat with his earlier one having three degrees of freedom, and he found that it directed the combined system into the meridian line. He then experimented with a single gyrostat having two degrees of freedom only, which, according to Foucault's law, should set itself with its axis of rotation parallel to the axis of the earth.

A toy or an experimental gyrostat does not exhibit any directive phenomenon. The existence of the directive force can be observed only when the speed of rotation is high, and when all precautions have been taken to eliminate friction. Although this is so, it is easy to demonstrate with an experimental gyrostat that if the spinning body has only two degrees of freedom the position of its axle and the direction of its rotation will be affected when the gyrostat as a whole is revolved.

Picture an experimental gyrostat suspended in gymbals so carefully that it has three degrees of freedom, so that it will take up a definite position in space. An experimenter may take this in his hand and turn round without affecting the gyrostat, but let him clamp the vertical spindle carrying the supporting frame, and the conditions are changed; the gyrostat has only two degrees of freedom. If the experimenter now revolves himself and carries the gyrostat with him, it will immediately set its axle parallel to the axis of rotation of the experimenter, which, of course, is vertical. We have supposed that the experimenter happened to revolve himself in the same direction as that in which the fly-wheel of the gyrostat was rotating. If he should revolve himself in the opposite direction, the gyrostat would immediately turn a somersault, and thus place its fly-wheel with its direction of rotation corresponding with the direction of revolution imposed upon it as a whole. It is quite obvious that a gyrostat with only two degrees of freedom behaves in a different manner to a gyrostat having three degrees of freedom.

The gyro-compass, as already indicated, is a gyrostat with only two degrees of freedom, so that it seeks to bring its axle parallel to the earth's axis, with its direction of spin the same as that of the earth. But the gyro-compass is floating in a bowl of mercury, and the axle of its fly-wheel will remain horizontal. It is clear that under these conditions the gyro-compass could not have its axle parallel to the earth's axis unless the apparatus happened to be at the equator. Although the gyrostat would tend to do so when carried north or south, it could not, as its axle would be pulled into a horizontal position by gravity. Those accustomed to experiment with gyrostats know what this means; the applied forces tend to set the axis of the gyrostat parallel to the earth's axis, causing the gyrostat to 'precess' or wheel round in a direction at right angles to the direction in which the applied forces tend to turn it.

This phenomenon of 'precession' is beautifully demonstrated by the well-known Wheatstone compound gyrostat, in which we may apply a weight to one end of the horizontal axle. Instead of tilting the axle, as would be the case if the fly-wheel were at rest, the applied force causes the gyrostat to wheel round, and it will continue this 'precession' so long as the force is applied. We have a demonstration of 'precession' in the school-boy's spinning top, and we know that the earth precesses, principally because of the attractive pull of the sun and moon on the oblate portion at the equator. We know that it is because of this precession that the north pole of the earth has not pointed always to the Pole Star, but that the earth's axis of revolution describes a curve, which is very nearly circular, about the pole of the ecliptic.

Even when one holds a toy gyrostat in one's hand, say with the axle horizontal, when one seeks to depress one end of the axle, there is not only a feeling of resistance, but a distinct twisting motion of the gyrostat. This we recognise as the wheeling round of the gyrostat at right angles to the applied force, or in a single word—its 'precession.'

It is this precessional motion which turns the gyro-compass into the desired position. The applied forces, due to gravity, keeping the axis of the gyrostat horizontal, cause the gyro-compass to wheel round until it gets into the position with its axle parallel with the meridian, in which position the gyrostat may be carried round by the earth without resistance. Should the axle swing beyond the meridian on the other side, the pull of gravity will be on the end of the axle opposite to that which we have been considering, and the precession will be in the opposite direction, bringing the axle of the gyro-compass back to the meridian.

One difficulty, in giving the gyro-compass only two degrees of freedom, was that such a gyrostat would be affected by other forces which might be brought to bear on it, as, for instance, by the movements of the ship. Such forces would set the gyrostat swinging, and render its indications unreliable. It became evident that if a gyro-compass were to be of practical value it would require to possess a very large gyroscopic resistance, strongly opposing any attempt to tilt its axle to an angle. Also that it would be necessary to have the friction of the suspension system as small as possible. But when these objects have been attained there remains a serious difficulty. If for any reason the gyrostat should be deflected a long way out of the meridian line, its swinging motion to and fro will last a very long time. This would render the gyroscope useless as a compass, unless it were possible to damp out this swinging motion. The first idea of overcoming this difficulty was to use a second gyrostat to damp out the oscillations, but it was soon found that a reliable damping could be obtained by a much simpler arrangement, which will be described when we consider the construction of the practical compass.

It need hardly be pointed out that although Foucault set forth the laws describing the actions of the gyrostat, it would have been quite impossible for him to produce a gyro-compass, as he had no means of supplying the necessary continuous motion to the fly-wheel, the rotary speed of which must be very high. Besides, in his day, there was no necessity for such a compass, as the simple magnetic compass would serve all practical requirements. Indeed, until recently it was found quite satisfactory to apply proper compensation to the magnetic compass to balance the attractive force of the iron in the ship. But with the increase in size of warships, and the great masses of moving steel in use in modern guns and their shields, this magnetic compensation became a very serious problem. Then, again, the submarine with its great number of electric motors, producing magnetic fields of their own, and thus affecting the compass, created a demand for a non-magnetic compass.

The practical construction of the gyro-compass will be understood from the accompanying diagram (Fig. 4), which represents a vertical section of the instrument. It will be observed that the gyrostat G runs on bearings fixed in the case C, which is suspended from a hollow steel ring F. This hollow vessel floats in a bowl B, also made of steel and filled with mercury as at M. It will be observed that the gyrostat is mounted at the lowest point of the moving system, with the spinning axle horizontal. The centre of gravity is below the meta-center (that point on the position of which its stability depends). The circular hollow float has a dome to which the compass card CC is rigidly fixed. The axle of the gyrostat is directly under the 'north' and 'south' of the card, so that when the gyrostat places its axle north and south, the compass card takes up the same position.

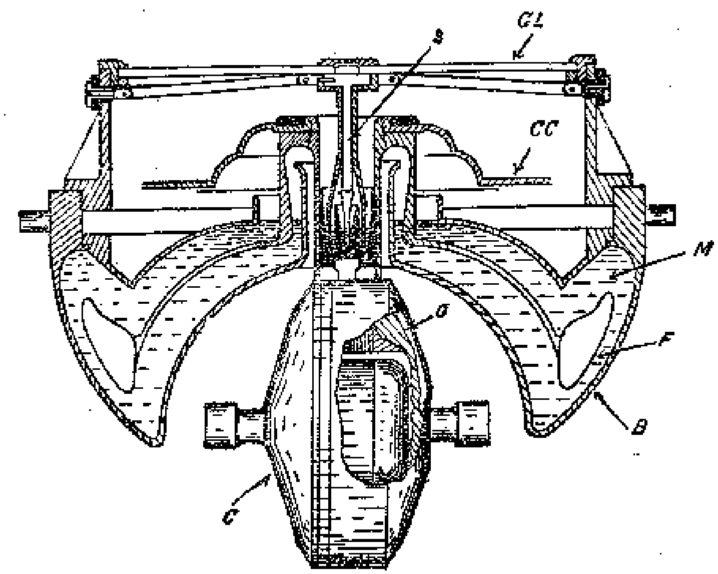

FIG. 4.
THE GYRO-COMPASS

C Case enclosing Gyrostat.
G Gyrostat.
B Bowl of mercury.
F Float.
M Mercury.
S Steel stem.
C C Compass card.
G L Glass cover.

The mercury bowl is carried on gymbals in the well-known manner, and the outer gymbal ring is borne by springs from the binnacle case, and so protecting it to a great extent from damage due to violent shocks. In order to keep the whole floating system central, a steel stem S is fixed centrally in the cover glass GL, and the lower end of the stem dips into a small mercury cup carried on the top of the float. This serves also as one of the contacts to conduct the electric current to the gyrostat motor. Around the steel stem S is a steel tube, there being an insulating material between them. It will be observed that the lower end of the tube is widened and dips into a second mercury cup. This serves as a second electrical contact. Both these contacts are, of course, insulated from the general metal portions of the apparatus. As the gyro-motor is a three-phase one, it requires a third electrical contact, and this is obtained through the mercury bowl, the mercury, and the float. This arrangement necessitates the whole instrument being insulated from the binnacle.

The motor of the gyrostat consists of a very small three-phase motor, the stator (fixed coils into which the live current enters) is mounted inside the case C, so that all the connections can be rigidly made. The rotor (the conductor in which only induced current flows) is rigidly fixed into the inside of the gyro-flywheel itself. This rotor has no coils of wire, only copper bars let into the fly-wheel. It is necessary to have the fly-wheel and axle made from one solid piece of special nickel steel, as the speed of rotation is to be about 20,000 revolutions per minute. This means that the peripheral speed of the gyrostat is almost six miles per minute. Its enormous speed may be realised if we think of the fly-wheel making 333 revolutions in each second. The stress to which the rim is subjected amounts to ten tons per square inch.

The axle is provided with ball bearings, which have to be so exactly gauged that special precision appliances have been devised to examine the spherical condition of the balls. The axle is of the de Laval type, forming a flexible axis, so that the centre of gravity of the whole rotating mass coincides with the rotation axis as soon as a critical speed is exceeded. Even although the axle is relatively weak, the gyrostat, while running, is not sensitive to shocks, because while even the very shortest possible shock lasts, the gyrostat has made many revolutions (333 revolutions per second), and therefore any bending tendencies neutralise one another.

It is interesting to note that about ninety-five percent of the motor energy is absorbed in overcoming the resistance of the air. The air friction on the surface of the gyrostat is so great that after the gyrostat has run for a few thousand hours its surface becomes noticeably smoother, having been polished by friction with the gaseous air particles.

It is this air disturbance which the inventor uses to damp the pendulum motion of the gyro-compass. The high speed of the gyrostat within its enclosing case practically forms a centrifugal blower. A hole near the centre in each side of the case C serves to admit air, and a hole in the periphery at the lowest point of the case acts as the outlet, and through this a constant stream of air issues. This constant flow of air through the case serves to keep the gyrostat cool, but what is of greater importance is that the energy of the escaping air may be used to damp out the pendulum motion of the instrument. One method employed by the inventor is to divide the outlet into two compartments having a movable division between them. This division practically forms the bob of a pendulum, which moving to one side decreases the size of that compartment and enlarges the other. The pendulum, which carries this division of the air outlet, is so balanced that when the axle of the gyrostat is horizontal, the division separates the air outlet into two chambers of equal area. In these circumstances the air is forced out with equal energy through both chambers, one part on each side of a vertical centre line through the whole moving system.

When the axle of the gyrostat is not horizontal, which is the case when the instrument is precessing to or from the meridian, the small pendulum swings to one side, and the two air passages are no longer equal; the difference of their reaction forms a turning couple round the vertical axis of the system. This couple produces a motion opposed to the precession, in such a direction as to bring the axle of the gyrostat to the horizontal once more. In this manner the oscillations of the gyrostat on either side of the meridian are powerfully damped.

Corrections require to be made for changes of latitude and for changes in the speed of the ship. These, however, are simpler than the corrections which have to be made in the readings of a magnetic compass, such as the continual secular change in 'variation.' The gyro-compass has a great advantage in pointing to the true north, and not to a certain spot known as the magnetic pole, from the direction of which the true north may be deduced.

So far as change of speed is concerned, it is obvious that this will cone into play only when the ship is steaming in a northerly or southerly direction. In such cases if the ship were stopped suddenly, there would be a pendulum motion of the suspended system; the gyrostat would swing forward by its own inertia. This tilting of the axle would cause a precession, producing an error. This is called the ballistic deflection, and is corrected by means of a simple table of figures. When a ship is going in an easterly or westerly direction, the pendulum motion of the suspended system is then about an axis parallel to the axle of the gyrostat, and therefore the gyro-axle moves parallel to itself, and there is no precession.

The directive force on the gyro-compass is fifteen times as great as in the case of a good magnetic compass, even when placed quite free of any surrounding iron. The value of the directive force of the magnetic compass decreases rapidly with the vicinity of large masses of iron and the presence of electric circuits, whereas the directive force of the gyro-compass remains constant under these circumstances.

Another advantage is that the compass card of the gyro-compass cannot roll about in any direction as can the card of the magnetic compass, whose point of support is at its centre only. The gyro-compass resists any alteration of its axle, both in a horizontal and vertical plane, and the compass card, therefore, can only see-saw up and down with the north and south line as an axis. Consequently, if an electrical contact point be placed at east and at west of the card, these points will not be rolled about which would alter their compass direction; they will move up and down only, remaining due east and west. This phenomenon makes it possible to construct a system of transmission mechanism which would be impossible with a magnetic compass in which the card can roll about in any direction.

Just as we have a master clock with a number of electric dials placed at a distance, so we may have a master compass with receivers placed in convenient positions on board a ship. One advantage in this arrangement is that the master compass with its gyrostat may be placed in some well-protected position near the bottom of the ship.

In the master compass, no actual work is put upon the gyrostat; it merely carries the contact points, and these control a reversible electric motor which turns the whole mercury bowl, causing it to follow the movements of the gyrostat. This reversible motor remains out of action so long as the ship keeps on a steady course, but any alteration in the course causes the gyrostat to switch on the current, in one direction or the other, to the motor. A commutator is mounted on the axle of the reversible motor, and this distributes electric energy to the mechanism of the receiving instruments, according to the position of the mercury bowl of the master compass, so that the receivers always turn in synchronism with the transmitter.

The receiving mechanism is connected by means of gearing to a compass card, and it is on these dials that the directions are read. In the centre of the receiving card is a second card, which makes one complete revolution for ten degrees of alteration of the course. This inner card is divided in such a manner that an alteration of a few 'minutes' is at once apparent. The employment of this fine adjustment is of the greatest possible assistance in steering. When the ship is in motion, the small central card is constantly on the move to and fro, on account of the ship continually departing from an absolutely straight course. So long as the movement is merely to and fro, the steersman knows that all is well, but a continued movement in either direction shows that an alteration of the course has taken place.

The high speed of the gyro-motor is obtained in this way. The three-phase portion of the motor generator has sixteen poles, and runs at a normal speed of 2500 revolutions per minute. As the motor in the gyrostat has only two poles, it follows that the speed of this latter is 16 x 2500 = 2 = 20,000 revolutions per minute. This is the limit of speed in practice, but for the purpose of testing that the factor of safety in the gyrostat is sufficiently high, a special motor generator was built to give an enormously increased periodicity. To make an exceptionally high speed possible, the gyrostat was run in a vacuum. We have seen that even at 20,000 revolutions per minute the centrifugal force is so great that the rim of the fly-wheel is subjected to a stress of ten tons per square inch. In the super-high speed trials it was found that the gyrostat could withstand not only double the strain, but the normal power had to he increased five times before any yielding of the material took place.

PREVENTION OF SHIPS ROLLING

Another gyrostatic invention of general interest has been made in connection with the rolling of ships. Of the three motions, heaving, pitching, and rolling, it is the last-mentioned which is feared most by those who dislike sea passages. Most of us do not worry about the heaving of a ship as it rises and falls bodily keeping its deck in a horizontal position; the greater the displacement the lower is the frequency. But the motion which is caused by pitching is not so pleasant, one may be moved up and down through a distance of thirty feet in a few seconds, but we can escape this motion almost entirely by getting amidships. There is no doubt that it is the rolling of a ship which brings about the discomforts of sea-sickness most easily. The vertical motion of the sides may be avoided by getting to the centre of the deck, but the angular movement cannot be evaded, a° it affects equally all parts of the ship.

Several inventors have suggested anti-rolling devices, but by far the most ingenious of these is the gyrostatic invention patented by Dr Otto Schlick, of Hamburg, an eminent marine engineer, who gave successful demonstrations of his apparatus both in his own and in this country.

It was the gyrostatic action of paddle wheels in a steamer which led Dr Schlick to study this subject. He had observed that when a steamer is heeled over by a wave, the course of the steamer is altered slightly, and conversely that when the course of a steamer is altered suddenly the steamer heels over. With an ordinary paddle steamer these phenomena are not very apparent, for the speed of rotation of the paddles is comparatively slow.

In order to study the subject, Dr Schlick used a model with two solid discs to represent the paddles. To increase the gyrostatic action, these were driven at a high speed, and the model ship was pivoted to permit of its turning freely upon a vertical axis. When this model was heeled over to starboard by the addition of a weight on that side, the how of the model turned to starboard. When the weight was transferred to the port side, the vessel turned to port. The same holds good in the case of an actual steamer on the water, but the amount of turning is very slight. The action is not what one would expect, for when a vessel is heeled over to starboard, the paddle on that side will get a bigger grip of the water, and one would expect the vessel to turn to port, but not so.

It was when studying these phenomena that Dr Schlick was led to the invention of his anti-rolling apparatus. In this case the gyrostat is not placed with its fly-wheel in a vertical position, as are the paddles of a steamer; the gyrostat revolves in a horizontal plane, with its axle vertical. It may be remarked that a gyrostat, if placed with its fly-wheel in a vertical plane, and its axis of rotation transverse to the ship, could be used in an anti-rolling device, but not so conveniently.

In Dr Schlick's invention the gyrostat is mounted in a frame which has trunnions or bearings at the sides, and is so placed that its pendulum motion will be fore and aft. Any attempt to tilt the vertical axle of the gyrostat from side to side will cause the gyrostat to swing at right angles to that, which will be lengthwise in the ship.

In connection with the gyro-compass, we have considered how the gyrostat's resistance is at right angles to the applied force. But the enforced pendulum motion of the gyrostat, swinging fore and aft, will not prevent the rolling of the vessel; it is necessary to oppose this force. This Dr Schlick has done by applying brakes to the swinging movement of the gyrostat frame. These brakes damp the pendulum motion and thus absorb the energy of the waves which tend to tilt the ship. The brakes may be either hydraulic or friction, but they must be automatic in their action.

Dr Schlick made an experiment with a German torpedo boat measuring 117 feet long by 12 feet 6 inches broad, and displacing 65 tons on a draft of 3 feet 6 inches. The meta-centric height was 1.3 feet, and the natural period of rolling was about 2.1) ?> seconds from side to side. Such a vessel would prove a very bad roller, as its natural period would be very similar to the period of the waves; the test, therefore, would be a severe one.

The gyrostat wheel was driven by steam, turbine blades being fixed on its circumference. The frame enclosing the gyrostat formed a steam-tight cast-iron casing, receiving and exhausting the steam through the trunnions on which the frame oscillated. The diameter of the steel fly-wheel of the gyrostat was 39 inches, and its speed of revolution was about 1600 revolutions per minute.

The hydraulic brake for controlling the oscillatory movement of the frame consists of a cylinder, with a piston forcing the fluid through a valve, the opening of which can be regulated from deck. The whole apparatus could be thrown in or out of action by means of a friction hand-brake, by which the gyrostat frame may be held in a fixed position or released as may be required.

All the trials at sea were most successful. The little vessel could be taken out into a rough sea, with the apparatus clamped out of action, so that the natural rolling might be witnessed, but as soon as a certain wheel on dock was turned, the rolling stopped almost immediately. So long as the gyrostat was left free to act, the vessel would defy the rolling motion of the waves.

When experiments were made in the Highlands of Scotland, on one of the steamers running between Oban and Tiree, where rolling is an almost constant complaint, the demonstration was entirely successful. On a sea which caused the ship to roll through an area of 32 degrees (while the gyrostat was in check), it was found possible to reduce the roll to four degrees whenever the apparatus was released. A rolling motion through only four degrees is quite inappreciable on any vessel.

When Dr Schlick propounded his theory in 1904, there was considerable discussion as to whether the steadying up of the ship would not be too great a strain on her. Some naval authorities declared that if a ship were stopped from rolling in a beam sea, the next wave would come on board. One speaker went so far as to declare that 'the rolling was provided by Nature to save the ship.' The reply to these statements was that no greater strain would be put upon the ship than was the case when a ship rolled through an angle of twenty-five degrees. Further, that the tendency to swamp the decks would be reduced instead of increased. This reply was endorsed by the great naval authority, Sir William White, I.C.B. It will be understood that a vessel equipped with the gyro-apparatus does not offer resistance such as a rock would do; the vessel is free to rise and fall in the water.

No anti-rolling device is necessary in very large steamers, such as Atlantic liners, for the bilge keels in these serve to prevent any cumulative rolling, and whatever pendulum motion there might be could not synchronize with the much shorter period of the waves. This is not the case with smaller steamers, and it remains to be seen in what direction the shipbuilders who own the Schlick patent will develop the invention.

BRENNAN MONO-RAIL CAR

Several systems of mono-rail tracks have been invented, such as a trestle arrangement upon which a divided car rides astride like the packs on the back of a donkey. One of the inventors spent as much as £40,000 on an experimental demonstration track, but so far none of these inventions have passed into the commercial world. There is a mono-rail track in Germany at Elberfeld, but in this case the rail is overhead and the ears are suspended from it. More interesting from the invention point of view is the gyrostatic car invented by Louis Brennan.

The inventor gave a demonstration, with a small ear, before the Royal Society (England) in 1907. Two years later he had an experimental track erected in the War Office grounds at Gillingham, Kent, where demonstrations were given with a full-sized car. This car measured 40 feet long, 10 feet wide, and 13 feet high. It weighed 22 tons, and was capable of carrying 40 passengers on an open platform. A little later Brennan gave some public demonstrations with this car, which naturally attracted a good deal of attention.

While it looked strange to see a heavy car running round a circular track on a single rail, and negotiating the curves as comfortably as a cyclist would, it was more surprising to see the loaded car stop and yet remain upright, even when its forty passengers all crowded to one side of the car. It goes without saying that the mere presence of a rotating gyrostat on board the car would not enable it to behave in this manner; it would only delay but not prevent the fall. It is necessary to have some means of raising the car automatically when it is tilted, and therein lies the ingenuity of Brennan's invention.

He employs two gyrostats mounted side by side in frames, each rotating about a horizontal axis. Each fly-wheel measures three and a half feet in diameter, and weighs about three-quarters of a ton. They are revolved in a vacuum at a speed of 3000 revolutions per minute, each revolving in an opposite direction to the other. The horizontal axles of the gyrostats are transverse to the ear, and are carried in gymbal frames. Each frame turns on a vertical axis, and attached to each of the two vertical spindles is a toothed sector. These two sectors engage with one another, so that as one frame turns about its vertical axis the other is forced to turn a similar amount, but in the opposite direction; if the one turns to the left, the other turns to the right. The object of this is to prevent any tendency of the gyrostats to check the free motion of the vehicle in making a sudden turn round a curve.

When considering the phenomena connected with Dr Schlick's model boat fitted with high speed gyrostats, it was observed that any sudden turning of the bow of the model caused it to tilt over, and it is apparent that this upsetting torque would be disastrous in the case of a gyrostatic car travelling round in a circle. But with the two gyrostats, as arranged in Brennan's car, the precessional couples are equal and opposite, and the trouble vanishes.

The gyrostats are mounted in gymbal frames, and these gyro-frames are carried in a single central frame, in which they both turn or 'precess.' This central frame is solidly mounted on an axis lengthwise of the car, and on the same level as the gyrostat axes, so that the car might tip over from side to side and yet the gyro-flywheels remain vertical. But the axles of the gyrostats project at the sides of the car, so that when the car tilts, a flat plate will come in contact with the axle and act as a friction surface. This pressure causes the gyrostat to precess about a vertical axis. The second gyrostat is forced by means of the toothed sector to turn equally in the opposite direction. The axle, on account of the friction on the contact plate along which it seeks to roll, has a force exerted on it whose moment tends to increase the precession. But the moment of this frictional force about a vertical axis has the effect, not to increase the precession already taking place, but instead to cause precession about the horizontal axis. This gives us two opposite moments acting on oppositely rotating gyrostats, so that they cause precession in the same direction about the horizontal axis of the car. This rights the car and tilts it slightly to the other side, to be brought back again by a second and similar friction plate on the other side of the car. The centre of gravity of the whole car is thus kept oscillating very slightly on either side of the line of upward thrust of the rail.

The gyro-frames, after the displacement, are brought back to their normal position, which is with the axles of the gyrostats transverse with the car. This is accomplished automatically by a second pair of plates, each engaging an idle or frictionless roller attached to the gyro-frames.

In considering the mere tilting of the car when at rest or on a straight line, the presence of two oppositely rotating gyrostats may seem to complicate matters unnecessarily, for a single gyrostat with friction plates would serve to right the car; the two gyrostats merely act in unison. But we have seen that when rounding a curve on the track the two gyrostats become necessary. When rounding a curve, the car is in balance, not when its centre of gravity is vertically over the rail, but when it lies in the line of the resultant of the centrifugal force and gravity.

The linking together of the two gyro-frames, by means of the two toothed sectors, is very ingenious. But for this connection the two oppositely rotating gyrostats would both maintain their original direction in space while the car turned the curve, but unable to do this because of the sectors, they are both forced to process with the car, and then the opposing forces come into play. The two gyrostats develop equal and opposite torques, which are transmitted to the rigid central frame, and they hold each other in equilibrium by means of internal stresses induced in the frame. If these forces were not opposing and neutralizing the torque of each other, the car would be overturned in seeking to round a curve.

The velocity of the gyrostats is high (3000 revolutions per minute), so that the mass of the fly-wheel may be kept small, and yet store the necessary amount of rotary energy.

In the full-sized car the prime mover is a petrol engine coupled directly to a dynamo. The electric current is distributed to two motors of 40 to 50 horse-power, placed on the bogies and conveying power to the wheels by means of an intermediate shaft. Electric current is distributed also to the gyrostats, the field magnets being on the gyro-frames, and the armatures on the gyro-axles.

One of the most interesting points in Brennan's invention is the means by which the car is automatically raised after being tilted to either side. The principle which he applied is the same as is present in the case of a rapidly-spinning top when 'sleeping.' The top rises to the vertical because of the precessional motion due to the friction between the point of the top and the ground. In the mono-rail car we have the friction between the end of the gyro-axles and the plates fixed on the sides of the car.

We are familiar with the fact that a gyrostatic top can balance itself upon an out-stretched length of string, and thus emulate a tight-rope walker. Brennan demonstrated that a passenger in his gyro-car could travel with safety on a suspended rope. One can imagine a very cheap form of suspension bridge if the gyro-car were to come into practical use, but despite the inventor's actual demonstration with a passenger, it might be difficult to persuade the public to cross a river or a deep ravine with a suspended rope as the sole track.

Chapter VII

Marine Inventions

Unsinkable ships—Marine Steam-turbine—Electric Propulsion—Jet Propulsion—Pendulum Propeller—Hydroplanes—Iceberg Detector.

Unsinkable Ships

After bulkhead-doors had been recognised to be a necessity for the safety of ships, there remained the danger of the men failing to close the doors. The loss of a large French steamer through this cause brought the subject into prominence, and efforts were made to provide some automatic means of closing all bulkhead-doors from the bridge. The apparatus known as the 'Stone-Lloyd system' came into favour very quickly, and is now in general use on all large liners.

It goes without saying that what is necessary is not only some automatic release of self-closing doors, for this would mean cutting off the possible escape of the men who happened to be working below. The invention provides against this, by leaving each door free to be opened by any individual desiring to pass through, after which the door closes automatically once more. Another necessity is that the doors must not be put out of action by any wilful tampering. When the invention was installed for the first time on a large liner (Kaiser Wilhelm der Grosse), some of the crew working below the water-line did not like the idea of a system of shutting the doors from the bridge. It seemed to them that in case of any accident they would be shut in and drowned like rats in a trap. Repeated demonstrations showing how the closed doors might be opened without difficulty by merely moving a small lever at the side of the door, one being on either side of the bulkhead, served to convince the majority of the crew that the invention was a safe one. But a few refused to be satisfied, and in order, as they thought, to protect themselves, they placed substantial props under some of the doors so that they could not be closed. On the next occasion when the captain tested the working of the doors from the bridge, his indicator showed him that these particular doors had not closed. A hasty examination by the captain and the engineer showed the cause, and brought trouble upon the men who had tampered with the system.

Should anything happen to go wrong with the closing apparatus of any particular door (a very improbable thing), the door closes of itself and will not remain open, although it can be operated by any one desiring to pass through it. The indicator shows the officer in charge that this particular door has closed when it ought to be open, and its mechanism is put right.

It will be of interest to see the means which are employed to bring about these different operations. The inventor (G. C. Ralston) made searching reliability tests with compressed air, electricity, steam, and hydraulic power, and he decided upon hydraulic power as being the most satisfactory motive power for closing and opening the doors; it is free from danger, easily understood, and may be kept in working order by any ordinary mechanic.

In addition to the hydraulic pressure pump, there are four capacious patent steam hydraulic accumulators, capable of supplying power in the event of the pumps being stopped. The hydraulic pump and accumulators are above the water-line, hence the pumps cannot be thrown out of action by water rising in the pump-room.

A branch from the pressure-mains rises to the bridge, where the pressure can be turned into either of two smaller pilot-mains running the whole length of the ship. One of these operates a controlling valve at each door, which in turn causes the door to close, while the other pilot-main operates the power for the reverse action, causing the door to open. Each door is fitted with a hydraulic cylinder, which operates a pinion engaging with a rack on the centre of the door. It is capable of exerting a force of about two tons when closing, and a greater force when opening the doors. This power is conveyed by the pressure-main, while the pilot-main merely operates the valves of the cylinders. Each of these valves is also under direct control by a lever placed on either side of the bulkhead, and it is by means of this lever that any one desiring to pass through may raise the door after it has been closed from the bridge. The door may be opened also by a hand-wheel operating directly on the pinion and rack.

When the doors are about to be closed from the bridge, a warning gong sounds, in each compartment, for about twenty seconds, to give men time to pass through the doors. If any one should happen to remain in the compartment after the door has closed, he has only to move the control lever, whereupon he reverses the action of the hydraulic cylinder, and the door opens to let him through, and then closes automatically behind him. If it should be thought necessary to close the doors during a fog, or when any danger seems imminent, the stokers may still draw coal from a water-tight bunker, by having a boy stationed at the door to hold the lever over in the lifting direction, thus keeping the door open as long as necessary. Immediately the boy lets go the lever, the door will close automatically.

In order to prevent the over-heating of the water in parts of the pressure-mains, which happen to pass across the top of the boilers, or in close proximity to steam pipes, the water is kept in constant circulation. To prevent the water freezing in the mains, some glycerine is added, there being one part of glycerine to three parts of water. This addition of glycerine serves as a lubricant to bearing surfaces, and as a preservative to packing and joints.

It will be observed that this automatic system has the great advantage of enabling the captain or other officer in command to close the doors in anticipation of an accident, instead of waiting till there is an impact. If desired, there can be added an automatic control for each door, by means of a bilge float, so that in the event of a sudden inrush of water, when the doors are open, the hydraulic valve will be thrown into action automatically. A further safety device may be added in the form of fusible plugs placed in the coal-bunkers, causing the doors to be closed automatically in case of fire. However, the main feature is the direct control of the automatic doors, by the officer in charge of the ship, leaving it possible for any one to escape, and still leaving the vessel in a water-tight condition. Despite the unfortunate loss of the Titanic, through an unlooked-for ripping of her side, there is no doubt that these automatic water-tight doors rank as one of the greatest contributions ever made towards the unsinkability of a ship.

MARINE STEAM-TURBINES

Apart from the steam yacht Turbinia, built in 1894, and two torpedo-boat destroyers ordered by the British Admiralty in 1899, the application of the steam-turbine to marine propulsion belongs to the present century. But the steam-turbine itself was well-established on land during the nineteenth century.

Up till 1909 there was no outstanding invention in connection with marine turbines, and even then it was a demand for some suitable intermediate gearing in order to make the high-speed turbine applicable to low-speed vessels of twelve knots and under. Mechanical gearing of the double helical type was introduced by the Parsons' Company, but this has little interest for the general reader. Single helical gear had proved remarkably free of the noise associated with geared wheels, the reason being that with helical gear there is always line contact between two meshing teeth. It was found, however, that the obliquity of the teeth set up side-thrust upon the wheel bearings, and to obviate this two separate wheels were used, their teeth being of opposite obliquity. In this way the one side-thrust neutralized the other. Finally the two teeth of opposite obliquity were combined on one wheel, producing a double helical gearing. The introduction of electrical gearing two years later has more interest to the outsider.

ELECTRIC PROPULSION

The introduction of a dynamo and a motor to act as gearing between the high-speed turbine and the necessary low-speed propeller-shaft was discussed in 1908 by W. P. Durntall, at the Institute of Marine Engineers, and a little later by Henry A. Mayor before the Institution of Civil Engineers, but the first practical demonstration was given by Henry A. Mayor, with the yacht *Electric Arc*, in 1911. This craft was directly under the control of the navigating officer on the bridge, leaving the engineer-in-charge free to attend to the running of the plant. By operating an ordinary engine-room telegraph on the bridge, the officer himself altered the speed, stopped the propeller, or reversed its direction, while the prime-mover continued at full speed in one direction.

This operation would involve the breaking of large currents which might damage the contacts of the main switch, but an inter-locking mechanism prevents this possibility. The opening and the closing of the circuit can take place only when the exciter circuit is open and no current is flowing.

A vessel of 250 feet in length, 42 feet 6 inches in breadth, 19 feet in depth, and adapted to carry 2400 tons of cargo was launched in 1913. The motor in this vessel, the *Tynemount*, is of novel construction. It is a three-phase squirrel cage motor, and has two separate windings, one of which is connected to an alternating dynamo having eight poles, while the other winding is connected to a second generator having six poles only. When these two currents of different periodicity are passing through the motor, it runs at full speed. But if one of the generators is switched off, the prime-mover may still run at full speed, while the motor having current in one winding only will run correspondingly slower. Each dynamo has a separate prime-mover, and if the lower speed is to be maintained for any time, the engine of the idle dynamo can be shut down.

It is obvious that even a turbine speed of 3000 revolutions per minute may be reduced to a propeller speed of 100 revolutions per minute, so that whatever the type of the prime-mover may be (steam, gas, or oil), it can be run at its maximum efficiency. It is evident, also, that the control of the ship is very simple, being governed by an electric switch. In this second Mayor boat, the *Tynemount*, the control has been placed in the engine-room, but if desired it can be on the bridge, as was the case in the *Electric Arc*.

JET PROPULSION

Attempts to propel a boat by the reaction of a jet of water discharged through a converging nozzle at her stern have not been successful from a commercial point of view, but as mentioned at page 126, this is deemed a possible field for the Humphrey explosion pump. The idea is attractive: a ship whose prime-mover is an explosion pump acting directly upon the water without any intervening pistons, cranks, shafts, or propellers.

Several fire-floats, stationed in canals and harbours, have been driven by jet propulsion, but in such cases the question of speed does not count. The pumping plant of the floating fire-engine has been used as the prime-mover. In one recent case, a boat 50 feet long, 11 feet broad, 5 feet deep, 3 feet draught, with a relatively small pumping outfit (1000 gallons per minute), was fitted with two one-and-a-half-inch nozzles fore and aft. The speed was only about five miles per hour, but the distances to be covered were very short. This method of propulsion was found to be extremely convenient for maneuvering purposes, as the boat could be steered and reversed by the operation of two valves. These valves are controlled by two levers, by means of which two jets of water can be sent astern for going ahead, or they can be directed forward for going astern, or with one jet forward and one jet astern, operating at opposite sides of the hull, the vessel can be turned round in her own length.

PENDULUM PROPELLERS

The screw-propeller has had a distinguished career during the two last generations, and still holds the foremost place in marine propulsion. Indeed, one finds it difficult to imagine any better mechanical means than to screw the ship's way through the water. But an inventor in Denmark has succeeded in propelling a ship in somewhat the same manner as a fish propels itself.

In this invention there is a pendulum propeller, which is analogous to the fish's tail. This propeller oscillated 180 double swings per minute, and produced a speed of 7.7 knots, when fitted in an officers' launch for the Russian Navy. The pendulum propeller was three feet long, with an area of 1*2 square feet, and weighed 40 lbs. Each swing was 72 degrees (30 degrees on each side of the vertical). In an attempt to increase the speed of the launch, the propeller was caused to oscillate 230 double swings per minute, but the vibration became very disagreeable. In any case, the increased oscillations did not advance the speed of the boat, but actually reduced it to 7.4 knots. In order to obtain a higher speed it was found necessary to increase the amplitude of the pendulum propeller instead of its frequency.

A vessel of 83.3 feet along the water-line, 19 feet broad, and with a draught of 8.3 feet was fitted with two pendulum propellers. These were arranged one on either side of the stern, and in this way it was found possible to dispense with the ordinary steering rudder.

The inventor claims that the pendulum propeller-rudders would render navigation much safer during foggy weather, or in navigating rivers and harbours, for no matter how little way the ship has on, the pendulum propellers can pull her stern round at once. The propellers are turned into any desired position by means of the steering wheel and a worm gear.

It is the novelty of the invention which interests us, but it may be noted that the inventor says (1913):—"The latest investigations have proved that two pendulum propellers, 12 feet long, and in certain positions in which they are able to swing 90 degrees instead of 60 degrees, can transmit, without any trouble, 1200 horse-power at 40 double swings per minute, sufficient for a ship of 8000 tons displacement at 10 knots."

HYDROPLANES

The idea of driving vessels over the water instead of through it is not new. A clergyman conceived the idea about fifty years ago; he even made experiments in the British Admiralty tank, but the weight of the steam-engine prevented success; the possible ratio of power to weight was very poor.

Some of us may remember that a very eminent scientist of last century declared that flying machines would be impossible for the very same reason, but the advent of the internal combustion engine altered the factors.

So long as a vessel had to be driven through the water, it was of little use to keep on adding more powerful engines, not because of the additional weight, but because of the fluid resistance (surface friction and wave-making) to the boat's motion. Of course, the internal combustion engine added great speed to small boats, as is evidenced by the fast-speed motor boats; but these also reach a speed limit because of the friction of the supporting fluid In the hydroplane this friction resistance is very greatly reduced; the boat is analogous to a skipping-stone, which, though heavier than its displaced water, remains on the surface by constantly moving over thy, water.

While at rest the hydroplane is floated in water, just as any other craft, by its static buoyancy; but when driven along by its engine at a high rate, the resistance of the plane bottom causes the boat to rise to the surface with very little displacement of water. In 1902 we thought twenty-one miles per hour an excellent speed for a motor boat, but the hydroplane can 'walk' round having attained a speed of forty-six miles per hour.

The hydro-aeroplane, sometimes called a water-plane or seaplane, belongs to the subject of aviation, which has been dealt with in a special volume in this series, by the well-known aviator, Claude Grahame-White.

SUBMARINE SOUND TELEGRAPHY

While it has been known for a very long time that water is an excellent conductor of sound, approximately five times better than air, it was not till the opening years of the present century that the knowledge was put to a practical use at sea.

The idea is to sound a gong below the water, say on a buoy or lightship, and to have a sound-receiver, also below the water, and attached to the hull of the steamer desiring to pick up such signals. The steamer itself is fitted also with a sounding gong, so that signals may be sent by it to other ships. The United States Navy have such apparatus installed on their submarines and on the parent ships, and it is claimed by American naval officers that it is this signalling apparatus which has enabled them to avoid such terrible disasters as have occurred to British and French submarines.

Some of the steamers plying between New York and Boston are equipped with sub-marine sound telegraphs, and signals may be picked up by a steamer when distant seven miles from the sounding gong. The receiver need not be on the outside of the hull, but may be clamped to the hull on the inside, for the sound vibrations can be transmitted through the iron plates to water in the receiver on the other side of the plates. The receiver consists of a cup-shaped metal cylinder, having the open end edged with rubber and clamped against the inside of the hull. There is a microphone of special construction contained in the sound-receiver, so that the sound-vibrations conducted by the water will control an electric current in the microphone. This electric current is conducted to an ordinary telephone receiver situated in the pilot-house.

The steamer has a sound-receiver on each side of the ship, and as the particular receiver which is acted upon more directly by the sound-vibrations will be operated much more vigorously than the other one situated on the opposite side of the ship, it is easy to detect from which direction the signals are proceeding. The exact location may be found by turning the ship's head about until both impulses are equal, and then noting the compass position. It is sufficient to have one telephone receiver with a switch, by means of which the receiver may be connected to either circuit at will.

It has been found that high-frequency vibrations carry better than those of lower frequency. The pitch of the bell which has been adopted by the United States Navy is about 1200 vibrations per second, the pitch of a soprano voice. The bell may be operate l compressed air or by electricity; or in the case of an isolated buoy the motive power may be obtained by means of a spring, which is wound up by the rise and fall of the buoy. Even in calm weather the ordinary swell is found to give several signals per minute.

The suggestion has been made that a steamer should carry a starboard and a port bell, each of different pitch, so that in foggy weather ships approaching one another might know exactly the position of the other—the case being analogous to what is done in clear weather at night by a starboard and a port lamp—each sending out a definite frequency of a ether waves.

ICEBERG DETECTOR

There are several inventions by which a distant iceberg may be detected and warning given on board an approaching vessel. One of the most ingenious of these is based upon a discovery of nearly a century ago that an electric current may be generated by heating or cooling the junction of two pieces of dissimilar metals. In the present case there are two half-rings of dissimilar metals, and a number of such couples form a thermopile. This current-generator may be placed on the hull of the vessel below the water-line. As in the case of the submarine telegraph, it is not necessary to have the apparatus on the outside of the hull. In the present case the thermopile is fixed to the inside of the hull, below the water-line, and the changes of temperature are conducted through the hull, iron being, of course, an excellent heat conductor.

If there is a cooling or chilling of the junctions in the thermopile the electric current will be generated in one direction, whereas an increase in temperature will generate a current in the opposite direction. These two different currents operate two different relays. The relay responding to the current generated by a decrease in temperature switches on a local current to a red lamp and to a shrill-sounding bell. The other relay, which responds to the current due to an increase of temperature, switches on a green lamp and a low-toned bell, while an indicator records the variations of temperature.

The signalling apparatus may be placed in the chart-house, the electric current being led there by means of wires from the detecting apparatus. There would be danger if the thermo-electric apparatus should happen to be out of working order when the officer in charge was depending upon it to give warning. This possible danger is obviated by the officer having a simple means of testing the apparatus at any moment. For this purpose a separate wire circuit is run down from the chart-house to the detecting apparatus. By closing a switch in the chart=house, an electric current heats a small resistance placed in proximity to the thermopile, and thus increases the temperature of the junctions. This will generate a current in the signalling circuit, causing the green lamp and low-toned bell to be energised, and the officer is satisfied that the apparatus is in good working order. The changes of temperature due to the presence of icebergs is very marked even several miles distant from the bergs.

That there does exist a very sharply defined change of temperature in the water is evident from a report which was made by one of the Inspectors of Lighthouses (Dominion Government), in the New York Sun of 26th May, 1912:

> "Latitude 41 degrees North, Longitude 50 degrees West. Approaching this vicinity from the eastward, . . . we got a temperature of 60 degrees at the bow and 48 degrees at the stern."

Within the next ten miles they encountered a huge iceberg.

CHAPTER VIII

MISCELLANEOUS INVENTIONS

COLOUR PHOTOGRAPHY—KINEMACOLOR—THERMIT WELDING—CUTTING METALS BY A FLAME—BLASTING WITH LIQUID AIR—NITRIC ACID FROM THE ATMOSPHERE THUNDER-STORM DETECTOR—MERCURY TELESCOPE.

COLOUR PHOTOGRAPHY

The practical methods of producing coloured photographs in the nineteenth century required the taking of three separate negatives, through red, green, and violet screens, from which three transparent positives were obtained. In order to view the photographs it was necessary either to shine three lights of the primary colours through the three transparencies (Ives process), or dye the transparencies the three complementary colours and superimpose them (Sanger-Shepherd process). There were exceptions, such as Lippmann's interference films and Wood's diffraction grating process, but these were entirely of scientific interest. Then came the Joly process, in which an attempt was made to put the three colour screens upon one glass plate, by ruling very fine parallel lines (red, green, and violet) all over the plate. The result is a finely-lined negative, from which a positive may be made and viewed through the colour-lined screen.

In the twentieth century a considerable advance has been made. In 1907, Auguste and Louis Lumiere, of Paris, invented a practical method of securing the three-colour impressions on one plate. They took potato starch, and converted it into round particles which are microscopic, measuring only about

nth part of an inch. These fine starch-grains were then divided into three portions and dyed, one portion orange-red, another green, and the third violet. They are then mixed together by a special machine, and the resulting powder is of a grayish colour. This powder is spread over a glass plate which has been covered with a film of gelatin. Some pressure is then applied so that the edges of the spherical grains touch as far as that is possible. The small interstices remaining are filled with very finely-divided carbon to prevent any white light getting through. This fine grain structure is then protected by a film of varnish, and on the top of this is applied the photographic emulsion, which, of course, must be panchromatic (sensitive to all coloured lights). All such emulsions are more sensitive to violet rays, and for this reason, in exposing the plate in the camera, the light is filtered through a yellow screen to subdue the violet rays.

The plate is exposed in the camera with the glass side towards the lens, and so the light passes through the coloured starch grain before it reaches the sensitized film. Red light can penetrate only the red starch grain, so that all the red rays will record their impression beneath red granules, green beneath green, and violet beneath violet granules. The light from a yellow object will register beneath the red and the green granules, as a yellow object reflects both red and green rays, and so on.

In developing the negative, the silver salt which has been exposed to light is reduced and obscures these granules which have transmitted light, and exposes those which have not permitted light to pass. If the negative be examined it will be found that what has been obtained is just the reverse of what is wanted. Where red light fell upon the plate, the red granules being obscured, the light will pass through the green and violet granules, producing a greenish-blue colour in place of red. Before fixing the chemicals on the photographic emulsion, however, the plate is immersed in a solution of potassium permanganate and sulphuric acid, which dissolves the reduced silver, but does not affect the silver salts which were protected by the coloured granules. The parts of the sensitized film upon which red light fell have the silver reduced by the action of the light; now that is dissolved, leaving the red granules transparent instead of obscure as at first, and so on with the green and the violet.

The next step is to take the plate, the chemicals being yet in an unfixed condition, and expose it to light for a short time, and then develop it for the second time. This will reduce the silver which had been protected formerly, so that in a part of the film which had been exposed to red light, the silver salts behind the green and violet will be covered by an opaque layer of reduced silver. Thus we get the true colours of the objects from the unobscure granules, and the reproduction of colours is wonderfully correct.

More recently the Paget process has been invented, but this is an adaptation of the Joly process, putting the colours on a screen in the form of tiny squares instead of in parallel lines. This process requires the registration of a colour screen in reproducing, as in the nineteenth century processes.

KINEMACOLOR

A few years ago two inventors (Urban and Smith) took out a patent for applying colour photography to kinematography. This was no easy matter. Already the moving pictures had to pass the lens at the rate of about one thousand per minute (sixteen per second). To throw red, green, and violet pictures in quick succession would mean an exposure of nearly 3000 pictures per minute, both in the taking and in the reproduction.

The inventors made a compromise; they were satisfied to use two components, red and green only. The long film in the kinemacolor contains alternate pictures taken through a red and a green screen, and these have to be reproduced time about through these two coloured screens. The kinematograph is driven twice as fast as usual, making about thirty-two exposures per second, and a revolving disc, containing a segment of red screen and a segment of green, revolves in front of the lens, in perfect step with the moving pictures. Of course, those colour combinations in which violet plays a prominent part must appear of a nondescript colour. The red, orange, yellow, and green can be fully represented, and the general colour effect is very good.

THERMIT WELDING

This invention, made by Dr Hans Goldschmidt, depends upon a very vigorous reaction between certain compounds. The object is to give a convenient method of welding without any heavy furnace or other apparatus. For instance, to weld a tramway rail by this process, while in position in the track, it is only necessary to place a simple mould around the joint and clamp a crucible on the mould. The crucible is filled with 'thermit,' and the reaction is started by a flame or by a red-hot iron bar.

Thermity is a mixture of a metallic oxide (usually iron) and pulverized aluminum, and when the reaction is once started between these two compounds the temperature quickly rises to about 3000 degrees. At this temperature the metal (say iron) of the oxide is given off in a pure state, free of carbon, and the pulverized aluminum unites with the oxygen of the oxide, and forms oxide of aluminum. The molten iron falls to the bottom of the crucible, and the light aluminum slag floats on the surface. A tap-hole is formed in a magnesia brick at the bottom of the crucible, and the hole is covered by a metal disc protected by two discs of asbestos. This plug or cover may be pushed in by means of a pin and lever, whereupon the mass of molten metal will flow from the crucible into the mould formed around the rail. The welded portion is found to be stronger than the rail itself, and under hydraulic pressure the break occurs outside the welded zone, the shoe of iron welded around the foot and web of the rail giving that part the additional strength. The process is of wide application, not being in any way confined to the welding of rails.

CUTTING METALS BY A FLAME

A well-known laboratory experiment is to burn iron nails or a steel watch-spring in an atmosphere of oxygen. The knowledge of this grabbing power of iron for oxygen is very old, but not till 1901 was it put to any practical use. The first application was to use an oxyhydrogen flame to remove solidified iron from the blow-holes of blast furnaces, but a few years later (1904) a new application was made, the cutting of heavy sheets of metal.

In 1909 it was found possible to cut through a 9-inch armour-plate of chrome steel, by means of an oxyhydric flame. The invention does not consist in merely blowing an oxyhydrogen flame upon the metal, but in blowing a high-pressure oxygen jet from a second nozzle, deflected so that the jet strikes the metal pre-heated by the oxyhydric flame. As this tool is moved along, the heating flame keeps bringing fresh metal to the combustion point, and the molten oxide which is formed on the surface is easily blown away by the high-pressure oxygen jet. The temperature is only about 1500° F., at which heat the iron has a great affinity for oxygen. The heat is confined to a narrow line, the properties of the materials cut not being affected beyond a1th of an inch of the cut surface. The result is a clean and narrow cut, just as though it had been made by some great knife.

When cutting very thick plates, a second heating nozzle may be added, but the principle is the same throughout, and even armour-plate of two feet in thickness may be cut through by the oxyhydric process. The cut need not be a straight line, but can be in a curve or any desired shape. The same principle may be applied to the cutting of apertures in plates or tubes, bolt holes in fish-plates, and such like.

The oxygen and hydrogen are stored in cylinders under a pressure of about 2000 pounds per square inch. Each cylinder has a needle-valve controlled by a pressure-regulator. The gases pass through heavily-armored tubes to the mixing chamber, which is surrounded by cold water to prevent any risk of explosion of the mixed gases. From the mixer the gases pass to the cutting tool.

BLASTING WITH LIQUID AIR

We have become quite familiar with the idea of ordinary air in a liquid condition, and many experiments with it are well known. Model locomotives and even full-sized motor-cars have been driven by its expansive force.

We know that the boiling point of liquid air is 190 degrees below the zero of the Centigrade scale (—300° F.). We require no very lively imagination to picture the result of liquid of that temperature coming in contact with masses of rock, the normal temperature of which is about 350° F. higher. There will be a very energetic exchange of temperature by heat conduction from the rock to the liquid, which will cause the liquid air to vaporize at an enormous rate. Indeed the difficulty in using liquid air in explosive cartridges was to prevent the air vaporizing before it was possible to fire the explosive. But during the early part of 1913 there was invented a reliable means of blasting with liquid air.

The invention is based upon a discovery which was made soon after the successful preparation of liquid air in quantities. It was found that charcoal at a low temperature was a great absorber of gases, and that a mixture of liquid air and charcoal may be highly explosive, when ignited by means of cartridges and fuses. The first attempts to put this discovery to practical use in mines was not encouraging, but two German engineers have now overcome the obstacle. Working in the Royal Quarries of Rudensdorf (near Berlin), the inventors conceived the idea of keeping the dry carbon and the liquid air separate until the explosive mixture was to be used. They introduced the cartridges with dry carbon into the blast-holes, and only added the liquid air when they were about to cause the explosion.

No dynamite or other explosive is used. A substantial pasteboard cylinder filled with an absolutely inert mixture of Kieselguhr and oil, asphalt, soot, or paraffin, is introduced into the blast-hole. This paper cylinder has a central tube which is perforated, and into which there is led a small supply tube, also made of paper. This small tube is to convey the liquid air to the cartridge when desired, and in order to discharge any products of vaporization of the liquid air, this tube has an outer jacket through which these products may escape. Several blast-holes may be fired simultaneously, all being connected by conductors to the igniting battery.

The liquid air is kept ready for each blast-hole in a special flask containing the required amount. These flasks carry at their opening a flexible metal tube, into which the central supply paper-tube is fitted. When the back end of the flask is lifted, the liquid air, under the pressure of its own products of vaporization, rises through the metal tube and through the paper tube into the cartridge. When the electric ignition takes place, the chemical combinations are so violent that a terrific explosion occurs.

This invention does away with the transport and storage of dangerous explosives, the liquid air plant being situated at the mine.

NITRIC ACID FROM THE ATMOSPHERE

For a century and a half we have known that an enormous store of nitrogen was all around us in the atmosphere, of which that element composes no less a proportion than four-fifths, but we had no means of obtaining this nitrogen in the form of nitrates, which are of great value as manures.

It is true that Cavendish showed how the nitrogen and oxygen of the air could be combined to form nitrous oxide by means of electric sparks, but it took Cavendish and his assistant a fortnight's continuous work day and night to produce an appreciable quantity of nitrous oxide. This compound is formed by combining equal quantities of nitrogen and oxygen. The compound nitrous oxide (NO) will combine with oxygen to form nitrogen peroxide (NO_2), and this gas is soluble in water (H_20), with which it combines to form nitric acid(HNO_3)

The twentieth century invention, by which nitric acid is obtained from the atmosphere, is practically Cavendish's old experiment on a very much larger scale. Several powerful electric arcs, with a potential of 33,000 volts, are produced in a dome-shaped combustion chamber. The air is admitted by means of a valve into the combustion chamber, where it is exposed to the intense flame of our arcs. The gases which leave the combustion chamber are nitric oxide, free nitrogen, and free oxygen. These gases are conducted to the combining vessels, in which the nitric oxide and the oxygen combine to form nitrogen peroxide. The gases then pass to the dissolving towers, where the nitrogen peroxide is dissolved in water to form nitric acid, and the free nitrogen escapes to the air.

The different processes, invented for the fixation of atmospheric oxygen, are all based upon the same general principle. The electrodes may be made of iron, and kept cool by water-circulation; they are able to withstand 200 working hours. Factories of 10,000 and 15,000 horse-power are at work.

THUNDER-STORM DETECTOR

Professor Turpain, of the Universite de Poitiers (France), has invented several instruments for recording and detecting approaching thunder-storms. As these instruments are to record electric impulses travelling through the tether of space, they are provided with aerials, and are in principle wireless receivers.

One of the most interesting forms of detector used by Professor Turpain is a coherer composed of a number of sewing needles placed crosswise, providing the orthodox loose contacts required in all coherers. The resistance in these loose contacts is sufficient to bar the way of a local battery current, but as soon as the incoming electric impulses from the tether are conducted by the aerial to the needles, they 'cohere' and allow the battery current to reach and operate the recording instrument. As soon as the local battery current rises to a certain point it causes an electro-magnet to operate a hammer and tap the board upon which the needles are held, and in this way they are decohered, and thus cut off the local battery, until a fresh charge is received from the aerial.

The recorder does not merely register the make and break of a sudden charge and discharge, but a sensitive galvanometer records the weak current passing through the needle contacts before their resistance is reduce I sufficiently to pass a current capable of operating the tapper. The galvanometer makes its record by means of a light pen upon a clockwork cylinder, similar to that of an ordinary barograph. Indeed the thunder-storm recorder is arranged sometimes to make its record alongside of a barograph on the same cylinder. The recording pen will be moved up and down leaving a tracing on the moving paper, then when the current rises high enough to operate the tapper, the pen will fall down to zero, and commence a fresh rise and fall, and so on. Of course, if the thunder-storm happened to be very distant, the varying record might be continuous for a long time, without the current ever rising high enough to operate the tapper and bring about a decoherence. By means of such instruments an approaching thunder-storm may be detected several hours before it arrives. Professor Turpain has devised a more sensitive form of recorder, in which a mirror galvanometer throws a beam of light upon a moving band of photographic paper. The mirror galvanometer is connected across a Wheatstone bridge, in which two very fine platinum wires are balanced against German-silver resistances. The fine platinum wires are protected from any local changes of temperature by being placed in double-walled silvered-glass vessels, made on the principle of the Dewar flask for holding liquid air (a vacuum space between the double walls). These platinum wires are connected to the aerial, and the electrical charge will heat the wires sufficiently to alter their electrical resistance, upsetting the electrical balance of the Wheatstone bridge, and causing the local battery current to flow through the mirror galvanometer. A more accurate reading of the thunder-storm may be obtained in this way, but the Wheatstone bridge apparatus requires careful adjustment and more attention than is demanded by the simple coherer apparatus.

MERCURY TELESCOPE

In 1908 Professor R. W. Wood (U.S.A.) invented a reflecting telescope, in which the magnification was obtained by a concave reflector of liquid mercury. The problem was how to rotate a basin of mercury without producing ripples on the surface of the mercury.

He tried many methods of transmitting the driving power to the basin. In one of these plans he had a rotating ring or collar surrounding the basin, but not touching it. On this ring he fixed a number of horse-shoe magnets, and on the basin he fixed a similar number of magnets. The opposing poles of the magnets faced one another in close proximity, but did not touch. When the outer ring was rotated, its magnets pulled the basin round also. However, it was found that the steady rotation of the mercury was quite as satisfactory when the power was conveyed directly to the basin by means of fine threads of India-rubber attaching the basin to the rotating ring.

The circular flat-bottomed basin is filled to a depth of half an inch with mercury, and when this is rotated with a uniform velocity the surface of the mercury assumes the form of a perfect concave paraboloid under the action of centrifugal force. With the low velocity of twelve revolutions per minute, the surface gives a focus of fifteen feet, while at a speed of twenty revolutions per minute the focal length is about three feet. It requires fully two minutes, after being set in motion, for the mercury to attain the same velocity as the basin. The mercury begins to spin first along the rim of the basin, the motion being gradually transmitted toward the centre.

The inventor describes his apparatus in the Astrophysical Journal and in the Scientific American, and he says: "As we stand beside the dish and watch the reflection of the room in the surface of the liquid, the effect is quite startling. The room appears to expand in a most remarkable manner, the ceiling retreating to a great height, and the walls moving outward."

The tube of the telescope consists of a cement pit fifteen feet deep and thirty inches in diameter. A chamber at the bottom of the pit contains the mirror and the electromotor, and access is obtained to this chamber by means of a separate shaft placed six feet from the telescope shaft. The actual observing, however, is done at the mouth of the pit. The star images are formed a little above the mouth of the pit, where they can be examined with an eye-piece.

Professor Wood tells of an amusing experience with an old inhabitant of the district in America in which his mercury telescope was erected, and the old man's philosophy will make a fitting sentence with which to close this little volume dealing with some of the twentieth century inventions.

The old man happened to come along as the inventor was examining the Milky Way, and the mouth of the telescope pit, which was formerly an old well in a shed adjoining a barn, was filled with hundreds of star images.

"What are they anyway?" asked the old man.

"Suns like ours, only bigger," replied the scientist, whereupon the old man queried,—"You don't say so; and have they earths and things going round 'em, and are they all inhabited?"

"Very likely," said the scientist; "Some people think so."

The old man scratched his head and turning to the scientist, he said,

"Well, do you know, I dunno as it makes so much difference after all whether Taft or Bryan is elected."