ELECTRICAL TRANSMISSION OF PHOTOGRAPHS

MARTIN

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BY

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"THE WIRELESS TRANSMISSION OF PHOTOGRAPHS"

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PREFACE

In this small volume the Author has endeavoured to present in a simple and concise form the method of working of the various systems devised for the electrical transmission of photographs over metallic conductors, and although quite a lot of experimental work has been carried out in this direction during the last few years, to many, even those with electrical knowledge, the principles are somewhat shrouded in mystery.

Although at present in a purely experimental stage, the science of photo-telegraphy is one that is rapidly growing in importance, and will, when perfected, no doubt prove a necessary and valuable adjunct to existing telegraph systems.

To those who are interested in original work, and who possess the necessary skill, a study of this subject will prove most interesting, opening up as it does a large and as yet little explored field for original research.

Short sections dealing with "Television" and the "Wireless Transmission of Photographs" have also been added, which will help the reader in becoming acquainted with the latest branches of photo-telegraphic work.

In order to assist those who desire to experiment, a chapter has been included containing full working drawings necessary for the construction of a machine suitable for either transmitting or receiving, and is similar in design to that used largely by the Author in his early experimental work. There are, no doubt, a great many interested in the subject of photo-telegraphy with a desire to experiment, but who have been deterred owing to a lack of knowledge regarding the methods of working and the type of apparatus employed, detailed information being very difficult to obtain. This chapter, therefore, will help the beginner over one of the chief difficulties, as the possession of a suitable machine is absolutely essential before any serious work can be undertaken, and the publication of working drawings of a machine actually built and used will save the intending experimenter a lot of time, money, and useless work.

A portion of the subject matter of this book originally appeared as a series of articles in *The Model Engineer*, and it is hoped that in their present amplified form they will prove of value and help to all who intend to make a study of this fascinating subject.

Chapter X, "Design for Experimental Machine for Photo-telegraphy," originally appeared as a short series of articles in the columns of *Work;* and I am indebted to Messrs. Cassell & Co., Ltd., the owners of the copyright, for their permission to re-publish the articles in this form.

I am also indebted to the Editor of the *Wireless World* for the loan of the original photographs for the blocks Figs. 19, 25, 32, and for permission to publish same.

M. J. M.

MAIDSTONE, 1921.

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CHAPTER I

INTRODUCTORY

HISTORICAL.

THE transmission of a photograph or picture to a distant point by electrical methods is a particularly fascinating problem, and one that has engaged the attention of electricians and scientists for a great number of years, numerous suggestions having been made and many experiments carried out for this purpose. The first experiments were made well over sixty years ago, but no great advance was made until 1907, when Prof. Korn brought out his now well-known selenium machines.

The early experimenters were faced with a great difficulty in the lack of possible application, and this is perhaps one reason why the early systems were never fully developed. With the ever increasing public demand for illustrated journalism that during the last ten years has sprung into being, this difficulty has been removed, and a large field of practical application opened up. The value of any system whereby a picture or photograph can be quickly and accurately telegraphed between places widely separated cannot be over-rated, and its useful application to newspaper work is at once apparent.

Practical Applications.

Since the advent of the Korn machines progress has been made to such an extent that previous to the outbreak of war in August, 1914, a large number of photographs were regularly telegraphed between London and Paris, Berlin and Paris, and many other photo-telegraphic stations, both in this country and abroad, for publication in the leading pictorial and daily papers, and perfection obtained to such an extent that the "wired" picture was sufficiently photographic to pass unobserved among the other news photographs in the paper in which it appeared.

Although barely emerged from the experimental stage, photo-telegraphy has already proved of great value as a means of quickly obtaining news pictures from the Continent, and on numerous occasions photographs of great public interest have been telegraphed to this country and published the same day, whereas at least two days would have elapsed before publication had the original photograph been sent direct by post. There is no question but that it is in the realms of journalism that the principal application of photo-telegraphy undoubtedly lies, but there are other channels of application that, once the commercial utility is firmly assured, will prove of great if not equal importance.

For military purposes, especially during wartime, photo-telegraphy will also prove of value, as maps, sketches of the positions of troops, etc., could be transmitted to different points with an enormous saving of both time and life. Photo-telegraphy also possesses criminalistic possibilities, as photographs of wanted criminals could be telegraphed to the various ports, both at home and abroad, and on more than one occasion photographs thus transmitted have proved of great value to the police authorities for identification purposes.

In view of these, and other applications that will with future improvements doubtless arise, it may be safely stated that there is every prospect of photo-telegraphy occupying a position of great practical utility, but to be commercially successful, any system of photo-telegraphy must be simple and reliable, and in these days of quick transit essentially rapid. At the present time a photograph having an area of about 30 square inches can be telegraphed a distance of three hundred miles in about ten minutes, while transmission has been effected between St. Louis and Cleveland, in America, a distance of some eight hundred miles.

From a perusal of this book and a study of the specimens of transmitted photographs, the reader may be led to suppose that the systems at present in use are very nearly perfect, but although a great deal has already been accomplished enabling a fair amount of success to be obtained, and many of the difficulties encountered in the early experiments having been overcome, there yet remains a vast amount of work to be done that opens up a large and as yet little explored field for original experimental work.

The systems at present in use are both good and practicable—it is perfection of detail that is required, and as the correct principles upon which the ultimate solution of this fascinating problem will be based are in all probability now known, it is safe to say that the difficulties remaining to be overcome are very largely of a mechanical nature.

To the uninitiated, the transmission of a photograph or picture to a distant point by electrical means must appear rather a difficult and complicated problem, but the telegraphing of a picture is, in many respects, similar to the telegraphing of a message. A message can be split up into separate letters, and by giving each letter a distinctive signal and transmitting the signals belonging to each letter in proper sequence, the operator at the receiving station is, by correctly arranging the signals and translating them according to some pre-arranged code, enabled to receive a copy of the message transmitted.

In the transmission of a photograph a somewhat similar cycle of operations is required. At the transmitting station it will be necessary to adopt some method whereby the photograph to be transmitted can be split up into its component parts, i.e. portions having the same density, and to so arrange matters that each portion can be transmitted separately and in succession, and also for portions corresponding in density to be given the same signal. At the receiving station we shall require some arrangement to record each signal in proper sequence, each signal being given the same relative area and having the same density as that portion of the picture that is being transmitted.

CHAPTER II

EARLY SYSTEMS

BEFORE proceeding to describe the modern systems that have been devised for the telegraphic transmission of photographs, it is proposed to give a brief review of the most prominent of the earlier attempts made to solve the problem, and which contain the germs of the ideas upon which the more successful of the recent systems are based.

BAIN'S CHEMICAL TELAUTOGRAPH.

The chemical telautograph of Bain, brought out in 1842, although only used for transmitting messages is worthy of mention, as it led to the work of Bakewell in 1847. The principle is as follows: The words to be telegraphed are compounded of large metal letters placed upon a metal plate, as shown in Fig. 1. These letters and plate are connected with the positive pole of a battery, the negative pole of which is connected to earth. The receiver consists of a metal plate, also connected to earth, upon which is fastened a sheet of paper that has been soaked in certain chemicals that can be decomposed electrolytically by the passage of an electric current through them. At both stations is arranged a brush M,M′, consisting of a number of metal springs, the two brushes being connected by the cable C,C′, in such a manner that the first spring on the transmitter is connected to the first spring on the receiver, and so on. If the brushes at both stations are moved over the metal plates at the same time and with the same velocity, a circuit is closed as often as a spring on the brush M comes in contact with the raised metal letters, and consequently a current flows which decomposes the chemical solution in the paper and leaves a

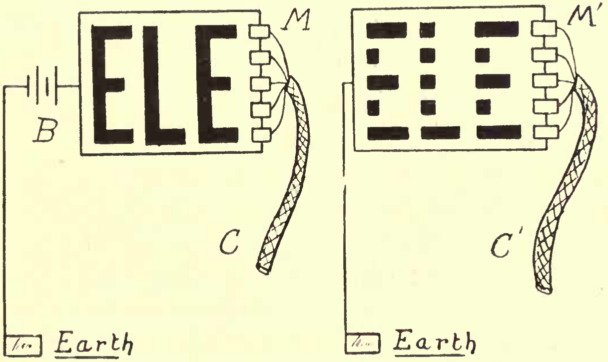


FIG. 1

coloured mark. The paper is saturated in a solution of potassium iodine in starch, the iodine being separated out by the current turning the starch blue, in which colour the words appear.

BAKEWELL'S TELAUTOGRAPH.

The telautograph of Bakewell, which created some attention in 1847, was the first practical system by which writing and even sketches could be transmitted electrically over a distance, and it is on similar lines that one of the more successful modern systems of photo-telegraphy is based.

Bakewell's apparatus, illustrated in its simplest form in Fig. 2, consists of two metal cylinders, A,B, which are revolved in synchronism. A spiral path is traced over the entire surface of the two cylinders by the metal, stylus S,S′, in a manner somewhat similar to an ordinary phonograph. Round the cylinder of the machine at the transmitting station a sheet of tinfoil is fastened upon which, in insulating ink, is drawn the matter to be transmitted, while

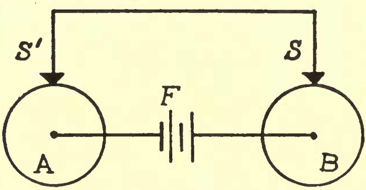


FIG. 2

the receiving cylinder carries a sheet of paper that has been soaked in a solution of potassium ferro-cyanide. As the stylus at the transmitting end traces over the sheet of foil, current from the battery F flows to the receiver and decomposes the solution in the paper, leaving a coloured mark.

All the time the transmitting stylus is in contact with clean foil the circuit is closed, but when it traces over an insulating line of the writing or drawing the circuit is broken. An intermittent current therefore flows through the receiver which produces coloured marks on the chemically prepared paper, a negative image of the matter transmitted being obtained.

With the cylinders revolving in synchronism some good specimens of writing and simple sketches were obtained, and at one time attempts were actually made in France to use the system commercially, but they were soon abandoned owing to the difficulties experienced at that time in working over long land lines and cables.

Caselli's Pan-telegraph.

This apparatus, which is a modification of Bakewell's, consisted of two curved metal plates rocked by electrical means, synchronism being obtained by means of a pendulum. The sketch or writing to be transmitted was drawn in insulating ink upon a sheet of metal foil which was stretched tightly over the curved copper plate used for transmitting, while over the curved plate at the receiving station was stretched a sheet of paper moistened with a solution of potassium ferro-cyanide. At both stations a metal stylus was arranged to press lightly upon the curved plates, and, as at the end of each "rock" the plates were shifted laterally, a series of parallel lines were traced over the entire surface. The two stations were connected electrically, and as the transmitting stylus traced over the portions of bare foil current flowed to the receiving machine, the solution in the paper was decomposed, and a coloured mark produced.

Charbonell's System.

It is fairly well known that the graduations in tone of an ordinary photographic negative are due to the action of light, in a greater or lesser degree, upon the silver nitrate contained in the gelatine film, and that the operations of developing, etc., removed the silver unaffected by the light. In a dense part of the negative the major portion of the silver would remain in the film, while in a transparent portion the silver would be entirely removed; therefore, according to the density of the image, more or less silver remains in the film. A transverse section of a photographic negative showing the deposit of silver in the film according to the graduation in tone is given in Fig. 3.

If we consider such a film to be mounted upon a thin metal instead of the customary glass base, and that it is fastened upon the drum of a machine similar to that used by Bakewell (Fig. 2), then if the film is in a moist condition, more current should flow through the line to the receiving apparatus when the stylus S traces over a dense portion of the film, as at A, than when it traces over portions B and C, as the conductivity of the film increases or decreases according to the varying amounts of silver retained.

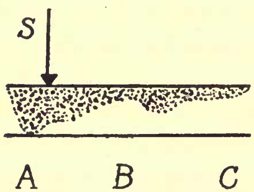


Fig. 3

The above is the principle of the method of transmitting that has been adopted by Charbonelle, a French postal engineer, in the system of phototelegraphy invented by him, and, although very ingenious, is of no real practical value, as the current values are of a very low magnitude, besides which the current cannot be relied upon to take a direct path through the film, the current always following the path of least resistance.

The receiver designed to work with this transmitter which sends out a constantly varying current, the strength of which is in proportion to the conductivity and therefore the density of that portion of the film that is passing under the stylus at any instant, consists of a telephone receiver with a hardened steel point fastened to the centre of the diaphragm. Wrapped tightly round the drum of the machine is a sheet of carbon paper placed between two sheets of thin white paper, the telephone receiver being so arranged that the steel point presses against the outer sheet of paper. As the diaphragm and steel point vibrate under the influence of the received currents, carbon marks are made on the inner paper, and these marks reproduce the picture transmitted. The results obtained with this receiver when working over short distances are stated to be very good.

There have been several attempts made to work with a transmitter similar in principle to Charbonelle's, but with little success, failure from a practical point of view being the normal result. One worker has endeavoured to utilize an image in relief (a carbon print) attached to a metal base and saturated in a badly conducting medium, so that the current flowing from the stylus through the carbon print to the metal base will vary according to the thickness of the gelatine film ; but here again the current variations are of such a low magnitude that it can only be employed to work over extremely short distances. This method has also proved rather uncertain in its action.

The employment of a photographic image in relief, and using the relief to vary the strength of the electric current, was first made by Amstutz, one of the early workers, and his idea has been followed up by a French inventor with great success. Amstutz was also the first to suggest the use of a single line half-tone photograph fastened upon a metal base for purposes of transmission.

Shelford Bidwell's Telephotograph.

The peculiar property possessed by prepared selenium of altering its electrical resistance according to the amount of light to which it is exposed was first applied, in connection with the attempts made to transmit electrically printed or written matter, drawings, etc, by Mr. Shelford Bidwell, a well known physicist. A diagrammatic representation showing the principles of his apparatus is given in Fig. 4.

The metal drum A, is mounted upon a steel shaft which has a fine thread cut upon it for part of its length. This shaft runs in two bearings, one of which is supplied with an internal thread corresponding with that on the shaft, so that in working the drum is given a lateral as well as a revolving movement, causing the platinum stylus S, to trace a spiral path over the entire surface of the drum. Round the drum is fastened a sheet of paper that has been soaked in iodide of potassium, which is a salt easily decomposed by means of an electric current

The stylus, which presses lightly upon the surface of the chemically prepared paper, is electrically connected through the variable resistance H with the positive pole of the battery B′, the circuit being completed through the metal framework of the machine and the galvanometer G. A second and equal battery B, whose current flows in a

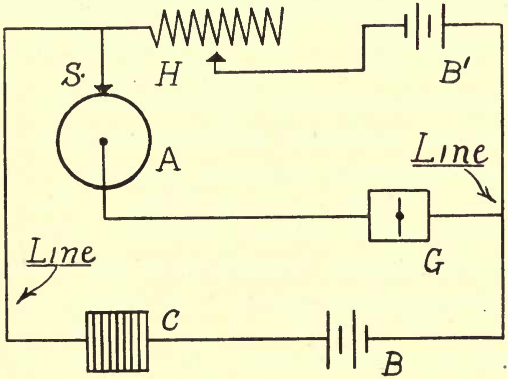


FIG. 4

direction opposite to that of B′, is connected in series with the selenium cell C,* this circuit also being completed through the galvanometer and machine. The resistance of the selenium is highest when unexposed to light, and by means of the variable resistance H, the resistance of the first circuit is made to equal the resistance of the selenium cell circuit with the cell in an unexposed condition, the galvanometer indicating when balance is obtained.

* A more detailed description of a selenium cell is given in Chapter IV. See also the *Wireless World* for January, 1916, Vol. III.

Suppose the conditions of both circuits to be equal, it is then evident that the current flowing from the batteries B and B′ will neutralize each other and no effect produced upon the chemical paper. If the resistance of either circuit is reduced, then a current equal to the difference will flow through the paper and produce a coloured mark.

In Bidwell's experimental machine the transmitter was so arranged that small portions of the matter to be transmitted were projected upon the face of the selenium cell in regular succession. When the cell was under the influence of a light portion of the image, the resistance of the cell was reduced and current flowed to the machine, and this current continued until the cell was shaded by a dark portion of the image, when the resistance of the cell rose to normal and the balance of the two circuits again restored. The reproduced picture was therefore formed by discontinuous coloured marks upon the chemical paper corresponding to the light and dark portions of the original. In order to obtain synchronism both the transmitting and receiving drums were mounted upon one shaft.

The best results with this apparatus were obtained when the picture to be transmitted comprised some bold subject in black and white, such as a sketch, or printed matter.

The Telewriter.

The telewriter is a piece of apparatus which gives a facsimile reproduction at the receiving station of anything written at the transmitting end, and although the transmission of handwriting cannot be classed with the transmission of pictures and photographs, yet, as some of the ideas involved are very ingenious, a brief description of several of the more noteworthy systems is retained as likely to be of interest. The following is a general idea of the principles of the apparatus invented by Mr. E. A. Cowper, of Westminster.

Two line wires are required which are severally connected with two galvanometers, the remaining terminals being connected to earth. The galvanometers are of the D'Arsonval, or moving coil type, whose coils are placed at right angles to each other, each of these coils being connected by a light thread to a pen, which is a capillary tube full of ink. At the transmitting station is a vertical pencil with two light rods jointed to it at right angles to each other, each rod guiding a contact block which slides over a special form of rheostat. The contact blocks are each connected with one pole of a battery, the other pole being connected to earth. The rheostats consist of a number of coils of different resistances, one end of each coil being connected with a copper plate, the other ends being joined together and connected to one unit of the telephone line; the copper plates are insulated from each other.

In order to better understand the working of the instrument let us consider one contact alone. We have already noted that each line is connected to its own galvanometer, and as the slide follows the movement of the pencil and moves over the rheostat in one direction or the other, more or less resistance is brought into the line, the strength of the current is altered, and the coil of the galvanometer more or less deflected. The other contact acts in a precisely similar manner, but whereas one contact produces an oscillation of the galvanometer coil which results in an up and down movement of the pen attached to it, the other contact produces a backward and forward motion of the pen. The action of the pencil at the transmitting instrument is to therefore vary simultaneously the strength of the two currents, these producing a motion of the receiving pen which is compounded of the two movements described, resulting in an exact reproduction, on a much smaller scale, of the original motion imparted to the transmitting pencil. The paper used at both stations is passed forward as the writing proceeds by means of clockwork.

Experiments show that this instrument will write through resistances equal to 36 miles of telephone line, while excellent results were obtained for some time over an actual line running between London and Woking. Apparatus on somewhat similar lines has been produced by Mr. Foster Ritchie, and Mr. Elisha Gray, who also experimented with a telewriter of his own invention between London and Dover.

As the range of movement of the pen in Mr. Cowper's instrument was very limited, it was entirely confined to the transmission of handwriting, and this constituted its chief drawback. In the receiving instrument of Grzanna's telewriter, the vertical and horizontal movements, corresponding to the variable currents sent out from the transmitter are communicated to a small mirror which is so mounted that it can turn about two axes, and a spot of light reflected from the mirror prints its message upon a sheet of photographic paper. As the spot of light acts as a very long weightless pointer, the range of movement is much more extended than the pen in Mr. Cowper's instrument, it being possible to transmit handwriting, drawings, and even dimensioned sketches, but the results obtained are not so satisfactory as the same matter would be if it were transmitted by any of the photo-telegraphic systems in use at the present time.

THE POLLAK-VIRAG WRITING TELEGRAPH.

In this instrument the mirror at the receiver is actuated by rods attached to the diaphragms of two telephone receivers. One telephone moves the mirror about a horizontal axis, and the other about a vertical axis, so that, by acting together, the telephones can cause the spot of light reflected by the mirror to trace any curve desired by the transmitter. The received characters are printed upon a strip of photographic film which is carried forward by clockwork, being afterwards run through the necessary developing, fixing and washing baths, when it is ready for use. This apparatus is only intended for the transmission of messages, drawings, etc., being impossible, and in trials made between Budapest and Pressburg this apparatus transmitted 450 words in fifteen seconds.

STANDARD TELEWRITER APPARATUS.

Standard telewriter sets, built by the London Telewriter Company, are made to operate on 36,

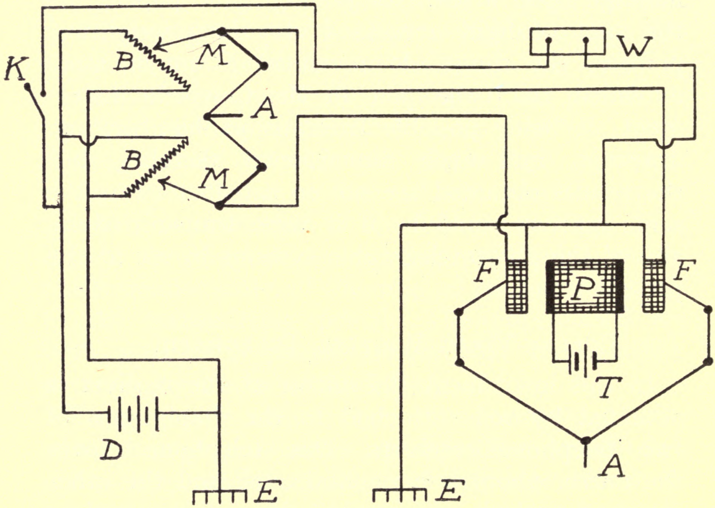


FIG. 5

110, and 230-volt circuits, the different sets varying from each other only in current consumption and resistance values. The 36-volt sets are, of course, only intended for work over comparatively short distances. A modified wiring diagram of a transmitting and receiving set combined is given in Fig. 5, the principle of working being on lines similar to what has already been explained. The movement of the transmitting pencil A is communicated to the two pivoted levers M, every movement of the pencil producing definite alterations in the values of the two rheostats B, which are traversed by current from a battery D. The levers M are connected by lines to one terminal each of the moving coils of the galvanometer, the other terminal being connected to earth. The moving coils F, which are spring controlled, are subjected to a common magnetic field produced by the coil P, which is energized by the battery T. The moving coils are also connected by means of pivoted levers to the pen A′, and both movements are so arranged that precisely the same range of movement is given to both A and A′. A call circuit is arranged as shown. If, as sometimes arranged, the transmitting battery is utilized for energizing the coil P at the receiving instrument, then five lines are required between the two stations, but if arranged as shown in the diagram only three are necessary.

The telewriter is a recent competitor to the telegraph and telephone, and it has already attained to a certain degree of prominence among business circles where there is need of a number of messages orders, etc., to be transmitted from a central station. As many as a hundred departments can, if required, simultaneously receive a message from a central station. Several telewriter exchanges have, for some considerable time, been in constant operation both in this country and on the Continent.

CHAPTER III

THE ELECTROGRAPH

THE Electrograph, the most noteworthy American system devised for photo-telegraphy, is the joint invention of Dr. W. P. Dunlay, H. R. Palmer, and T. Mills. In some exhaustive trials made with these machines over the Western Union American Telegraph and Telephone Company and the Associated Press lines, the apparatus operated perfectly, the results obtained, from an experimental point of view, being very satisfactory.

ITS OPERATION.

An etched zinc plate enlargement is prepared by the half-tone method of the picture or photograph to be transmitted, the recessed portions of the plate caused by the etching being filled with a fairly hard insulating material. The surface of the zinc plate when treated in this manner is fairly smooth, being partly metallic, partly insulating. Briefly, the method of preparing these zinc enlargements is as follows—

The picture or photograph which is to be transmitted is fastened out perfectly flat upon a copying board, a strong light being placed on either side of the board and concentrated upon the picture by means of reflectors. The camera which is used for copying has a "cross line screen" interposed between the lens and the sensitized photographic plate, and the effect of this screen is to split up the different tones of the original picture to be copied so that they may be represented on the negative as opaque dots of various sizes. Line screens consist of glass plates upon which a number of lines are accurately ruled, the width of the lines and the spaces between being equal; the lines are filled in with an opaque substance. The "cross line screen" used is composed of two single line screens placed with their lines at an angle of 90° to one another. The screens can be obtained with lines varying in number from 35 to 400 to the inch.

Now let us see what effect this cross line screen has upon the photographic negative. The light reflected from the original copy has to work its way through the mesh of the screen before it reaches the plate, and even the faintest light will penetrate through the centre of a square of the screen and register itself as a small dot on the plate. The more light that penetrates through the mesh of the screen the larger will be the size of the recorded dots. Thus the light reflected from the highest lights of the original (the white portions) will cause such a powerful action on the negative that the dot formed will reach right to the edge of the square, and will even cut its way right under the lines surrounding it, so that the dots are almost joined together, while in the darker portions, the "half-tones," the dots are of a size equal to the clear spaces between them, similar to the black squares on a chess board. The photograph, Fig. 6, shows the graduations in tone of an image, ranging from black to white, when broken up by a cross screen.

From this half-tone negative it will be necessary, after development, to take off a print upon a sheet of specially prepared metal, which in this case consists of a sheet of zinc coated upon one side with a thin film of glue to which bichromate of potash has been added; the bichromate possessing the property

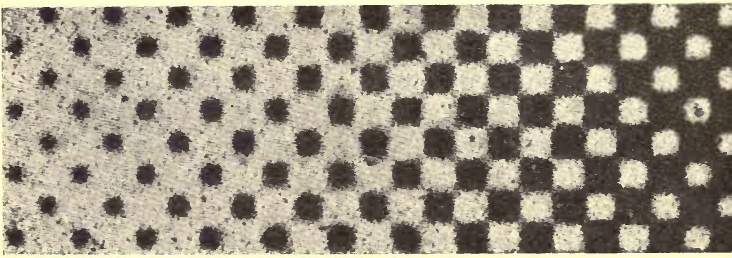


FIG. 6

SECTION OF IMAGE BROKEN UP BY A "CROSS SCREEN"

of rendering the glue waterproof when acted upon by light. The printing is usually carried out with artificial light, and when finished the metal print is washed in cold water, when all those parts not acted upon by light, i.e. the parts between the dots, are washed away, leaving the bare metal. After drying, the zinc plate is placed in a bath containing a solution of nitric acid, which etches away those portions of the plate that are not protected by the bichromated film. The etching is finished when the pure white portions of the original are represented by dots as fine as needle points on the metal plate. The back and edges of the plate are coated with bitumen varnish to resist the action of the acid, being removed at the finish by the application of benzine. The glue film, or " resist," as it is termed, which still adheres to the surface of the zinc plate, is now removed, and the etched portions of the plate filled in with a hard insulating substance, so that the whole presents a perfectly smooth surface. In some instances, small half-tone negatives of the subject were prepared, from which the zinc plate enlargements were obtained in the ordinary photographic manner, this method being slightly cheaper than making direct line negatives of the required size.

THE APPARATUS.

The machines used at both stations are similar in size and construction, so that one machine can be used for either receiving or transmitting. A diagrammatic representation of a machine is given in Fig. 7. As will be seen, the machine consists of a metal cylinder A, which turns between centres, and this cylinder is connected by gearing to a steel spindle S, also running between centres, upon which a fine screw thread is cut. A table T is arranged with a half-nut at one end to fit over the threaded steel shaft, the other end being fitted with a slide D, which runs along the guide bar G. The whole arrangement is driven through gearing by a 110-volt direct current motor.

Upon the table T is fastened a metal stylus for transmitting purposes and an electrically operated pen for receiving purposes, and so arranged that either can be placed in or out of operative position. As the cylinder of the machine is re-

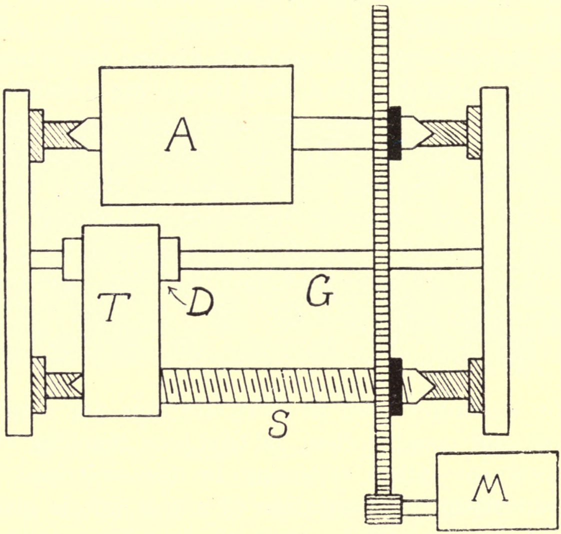


Fig. 7

volved, the table is given a lateral movement by reason of the screwed shaft and half-nut, causing the pen or stylus to trace a spiral path over the entire surface of the cylinder. Round the cylinder of the machine used for transmitting is fastened the zinc enlargement, and as the stylus traces its path over the surface a series of intermittent currents are sent through the line to the receiving machine ;

the circuit being completed when the stylus traces over a metallic portion of the plate, and broken when tracing over an insulated portion. The function of the transmitter is therefore to send out an intermittent current of varying duration which can be utilized at the receiving machine for reproducing the original picture.

At the receiving station a sheet of white paper is fastened round the cylinder of the machine,

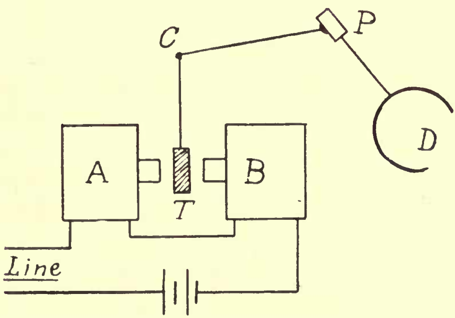


FIG. 8

black ink marks being made upon the surface by means of a pen every time a current is sent out from the transmitting station, the length of the mark depending on the duration of contact between the stylus and the metallic portion of the zinc plate.

This pen, shown in diagram form in Fig. 8, is of special construction and, according to the inventors, will make a perfectly black ink mark on the paper at a speed of 150 line impulses a second when operated with a current of about ·005 ampere. As will be seen from the diagram, it consists of an armature T, pivoted between two pairs of coils, the armature carrying an ordinary steel pen which just clears the surface of the sheet of paper when the armature is in its normal position, i.e. at rest. The two pairs of coils are electrically connected in series and connected direct to the line, so that both pairs are energized at the same instant by the line currents. The two main operating coils A possess cores of very soft Swedish iron, while the two opposing coils B possess cores of harder material. The action is as follows: Upon receipt of the line current both pairs of coils are energized, but the cores of the coils A become magnetized quicker than the cores of the coils B, the armature being attracted towards A before B has become magnetized sufficiently to offer any counter attraction. When the armature is in this position the pen is pressing upon the sheet of paper producing a black mark, continuing as long as the line current is flowing. Upon the line current ceasing to flow the cores of the coils A become demagnetized much quicker than the cores of B, which have a greater magnetic lag, and which retain their magnetism for a length of time sufficient to pull the armature back to its normal position. With this arrangement no retracting spring is necessary to bring the armature back to normal, and as there is no extra force for the coils A to overcome in order to produce motion of the armature, such as there would be if a retracting spring was used, it is possible to work at fairly high speeds with very weak line currents.

How Synchronism is Obtained.

It is obvious that the two machines must revolve in synchronism in order to obtain intelligible results, and the method employed is very similar to that which will be described in detail when dealing with Prof. Korn's system. The speed of the motors is controlled by a regulating resistance placed in the shunt field circuit in the ordinary manner, the transmitting machine being arranged to travel slightly faster than the receiving machine. When the transmitting cylinder has completed one revolution, a pin projecting from the shaft engages with a catch which prevents the cylinder from turning until a similar pin on the receiving machine slides over a contact spring. Upon the making of this contact, the circuit is completed of an electro-magnet which withdraws the catch engaging the pin on the transmitting machine, allowing it to revolve for one more revolution, when the cycle of operations is again repeated. Both machines therefore start a fresh revolution at the same instant, and an accumulation of errors avoided, as any difference of speed is adjusted at the end of each revolution.

Speed of Transmission.

The time required to prepare an enlargement and transmit the picture over a fairly short line is about 80 minutes, and of this time about 40 minutes are required to prepare the zinc plate enlargement, 30 minutes to reduce and prepare the received picture for newspaper printing, and 10 minutes for actual transmission. Some fairly good results were obtained over a telegraph line some 770 miles in length running between St. Louis and Cleveland, in America. A portrait transmitted by this system was seen by the writer some years ago, but the quality, although far in advance of anything that had been achieved previously, was not so good as that obtained about the same time by Prof. Korn in Germany, and Prof. Belin in France. Over longer lines, where it is necessary to use a repeater, the speed of transmission is reduced by about two-thirds.

The thread cut upon the steel shaft of the machine (Fig. 7), is such that the pen or stylus rules 40 lines to the inch, and the table travels laterally at the rate of one inch per minute. It is obviously necessary to employ an enlargement for transmitting, as, if a metal print the same size as the original was prepared from a " cross screen " fine enough to preserve reasonable detail, the stylus in tracing over the surface of the print would, in places, touch two dots at once, and so cause interference which would produce a blurred image at the receiver. This action would take place in the half-tones, with the result that the half-tones would lose their effect and mostly be reproduced with the high lights of the original picture. By enlarging the metal print, both the metallic dots and the insulating spaces are correspondingly enlarged and clear transmission facilitated.

At the same time this enlarging of the metal print precludes the transmission of any subject that contains any great amount of "fine detail," but this objection could be overcome by employing a much larger print (the size of print ordinarily used is about 30 cm. by 22 cm.), which, however, would render the rate of transmission too slow for practical purposes, besides being too costly.

CHAPTER IV

PROF. KORN'S SELENIUM MACHINES

To Prof. Korn, a German scientist, must be given the credit for bringing out the first practical photo-telegraphic system that was used for commercial purposes.

As far back as 1903, demonstrations of his system were given by Prof. Korn, and improvements worked out so rapidly that by 1907 a service was started between London and Paris, and later between London and Manchester, with great success, and it is from this date that the commercial history of photo-telegraphy really commences.

The Transmitter.

A diagrammatic representation of Prof. Korn's transmitting arrangements is given in Fig. 9. As will be seen, it consists of a glass cylinder C, fastened at one end to a steel shaft B, that has been screwed along part of its length. This shaft runs in two bearings, one bearing being plain, the other bearing A being fitted with an internal thread to correspond with that cut on the shaft. The shaft and glass cylinder is connected to the motor M by means of the flexible coupling F.

In front of the glass cylinder is placed a metal screen H, containing a small aperture *t*, and rays from a source of light L are focused by means of the condenser N upon the aperture *t*, after which they pass through the glass cylinder C and diverge upon the prism D, which in turn refracts the rays upon the face of the selenium cell S, the selenium cell being an instrument capable of altering its electrical resistance according to the amount of light to which it is exposed. Now imagine a photographic negative, one taken upon a flexible celluloid,

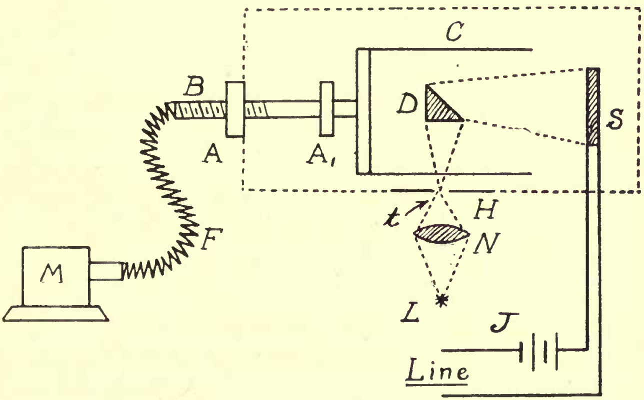


FIG. 9

instead of the ordinary glass, base, to be wrapped round the cylinder C. It is evident that when the motor M is running two movements will be imparted to the cylinder, a revolving as well as a lateral movement, caused by the screwed shaft and bearing A, and that the whole of the negative upon the cylinder will pass in turn across the aperture *t*.

As small portions of the negative pass in front of the aperture, the light from L, which falls upon the prism D, is constantly varying in intensity, and this variation depends upon the density of that portion of the photographic negative which is passing in front of the aperture. The varying light, which is projected upon the face of the selenium cell, causes a corresponding variation in its resistance, and this varying resistance regulates the amount of current which flows from the battery J through the line to the receiving instruments. The function of the transmitter is, therefore, to send to the receiving station as unidirectional current, the intensity of which varies in accordance with the photographic negative which is wrapped round the transmitting cylinder.

Seeing that the selenium cell plays such an important part in the transmitter, it will perhaps be as well to give a brief description of its construction and application to photo-telegraphic work.

Selenium, belonging to the sulphur and tellurium family, is a non-metallic element, greyish in colour, and in its natural state is practically a non-conductor of electricity, but Knox, in 1837, found that on being annealed it became a high resistance conductor, its resistance being (40×10^9) times greater than copper. The process of annealing consists in heating the selenium for some time to about 100°C., at which temperature selenium melts, and allowing it to cool gradually, when it will be found to have assumed a crystalline condition, and to have changed from grey to a dull slate colour. The commercial value of selenium consists of the property which it possesses, discovered by May, in 1861, that when in a prepared state it is able to alter its resistance according to the amount of light to which it is exposed.

THE SELENIUM CELL.

For convenience in using the selenium is made up into what is technically termed a selenium "cell."

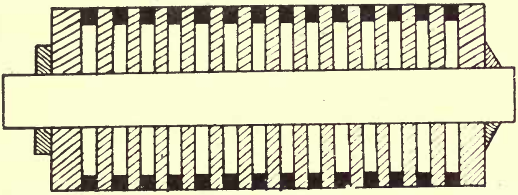


FIG. 10

The form given by Bell and Tainter to the cells used in their experiments in 1879 is given in Fig. 10. As will be seen from the drawing, it consists of a number of circular brass plates, separated by thin sheets of mica, slightly smaller in diameter, the whole being tightly clamped together upon an insulated rod. The whole arrangement is then heated to a temperature of 100°C., and selenium run into the circular spaces between the brass plates. The plates are connected in parallel, as shown in Fig. 11, all the even numbers joined together and connected to the terminal A, and all the odd numbers joined together and connected to terminal B. In the drawings the shaded portions represent the brass plates, the white portions mica, and the dark portions selenium.

Mercadier adopted a slightly different method of constructing his cells as will be seen from Fig. 12. Two long brass bands, 0·5 in. wide and 0·004 in. thick, are coiled as shown in the figure, the brass

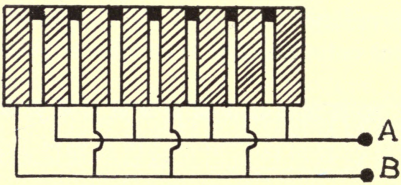


FIG. 11

bands being insulated from each other by having parchment strips between them. The dotted lines D represent one band, and the full lines S the other. The coil is tightly clamped in a wooden frame,

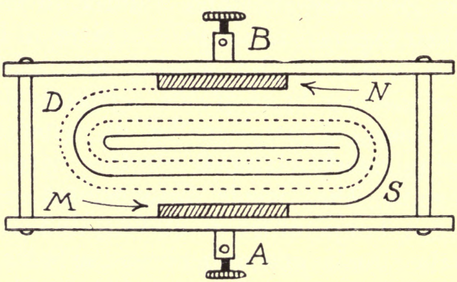


FIG. 12

and the finishing ends of the coil are connected to the brass plates, M and N, which carry the binding screws, A and B. One side of the coil was then polished, and after being heated in a sand bath until the desired temperature was reached, the polished surface was coated with a thin layer of selenium, and the whole allowed to cool gradually; the selenium surface was protected by a thin mica plate.

The modern cells are fairly simple to construct, consisting, as will be seen from Fig. 13, of a rectangular piece of slate, mica, porcelain, or other insulator, upon which fine platinum wire is wound,

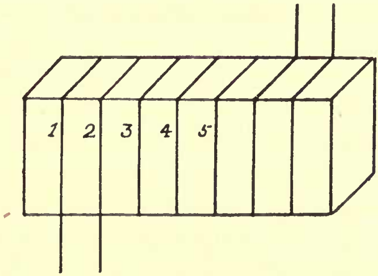


Fig. 13

the wire being wound double at even distances over the surface of the insulator. The crystallized selenium is placed between the wires and forms a high resistance conductor between them.

As the resistance of a cell depends to a great extent upon the transverse section of the selenium between the electrodes, it is evident that by varying the thickness of the insulating strips and so varying the transverse section of the selenium, cells of any required resistance can be constructed, while by using a number of elements connected in parallel, a very large active surface can be obtained. Thus cells have been constructed with a resistance as low as 40 ohms and as high as 1,000,000 ohms. The resistance of a selenium cell made on the principle given in Fig. 13, and measuring 65 × 25 mm., may be anything from 20,000 to 300,000 ohms.

Bell found that the resistance of a cell was decreased 50% when brought from a dark room and exposed to bright daylight. The light from a 20 c.p. lamp, when held a few inches away, will reduce the resistance of a cell of 250,000 ohms to about 150,000 ohms. A strong light falling upon a cell lowers its resistance, and vice versa, the resistance of a cell being at its highest when unexposed to light, the light being apparently absorbed and made to do work by varying the electrical resistance of the selenium.

A selenium cell, owing to its somewhat similar behaviour, is sometimes referred to as a "light microphone," inasmuch as its action under the influence of light resembles the action of a microphone under the influence of sound. The peculiar property possessed by crystallized selenium of reducing its electrical resistance when under exposure to light has been the subject of the investigations of many eminent physicists, but the most generally accepted theory is that put forward by Profs. Adams and Day, in 1877, the results of their exhaustive investigations leading them to suppose that "the electrical conductivity of selenium is electrolytic." The action of light in altering the electrical conductivity of crystalline selenium is supposed by these experimenters, who carried out a number of original experiments to support their theory, to arise from a modification of the crystalline condition when under the influence of light, and in their own words the explanation is as follows: "Light, as we know, in the case of some bodies tends to promote crystallization, and when it falls upon a surface of selenium tends to promote crystallization in the exterior layer, and therefore to produce a flow of energy from within outwards, which under certain circumstances appears in the case of selenium to produce an electric current. The crystallization produced in selenium by light may also account for the diminution in the resistance of the selenium when a current from a battery is passing through it, for in changing to the crystalline state selenium becomes a better conductor of electricity."

OPTICAL INERTIA.

The ability of a cell to respond to very rapid changes in the illumination to which it is exposed is determined largely upon its inertia, it being taken as a general rule that the higher the resistance of a cell the less the inertia, and that the lower the resistance of a cell the greater the inertia, and also that the higher the resistance the greater the ratio of sensitiveness. The sensitiveness of a cell is the ratio between its resistance in the dark and its resistance when illuminated. The majority of cells have a ratio of between 2·1 and 3·1, but Prof. Korn has shown mathematically that by conforming to certain conditions regarding the construction the ratio of sensitiveness may be between 4·1 and 5·1.

The inertia of a cell plays an important part when working, slightly opposing the drop in resistance when illuminated, and opposing to a greater degree the return to normal for no-illumination. It has been found by direct experiment that when a cell is first illuminated the current value rapidly increases, but if, after the cell has been illuminated for a short period the illumination is cut off, the current value, instead of returning at once to normal for no-illumination, only partially rises owing to the interference of the inertia, and some time elapses, varying from a few seconds to several minutes, before the cell returns to its normal condition, the actual time depending upon the characteristics of the cell and the intensity of the illumination to which it is exposed. An actual curve obtained from a cell is given in Fig. 14.

The comparative slowness of selenium in responding to any great changes in the illumination offers a serious difficulty to its use in photo-telegraphy, and this will more readily be understood by considering the conditions of actual transmission with the apparatus shown in Fig. 9. We have already noted that a photographic negative has been wrapped round the drum of the machine, and that the image on such a negative is composed of numerous portions of varying density, the density depending upon the amount of silver retained in the film. Now when working, let us imagine that light from the lamp L, passes through a transparent portion of the negative, and that it is immediately followed by an opaque portion. When the light passes through the transparent portion the resistance of the selenium cells falls to a certain value, but does not return to normal the instant the light is cut off by the

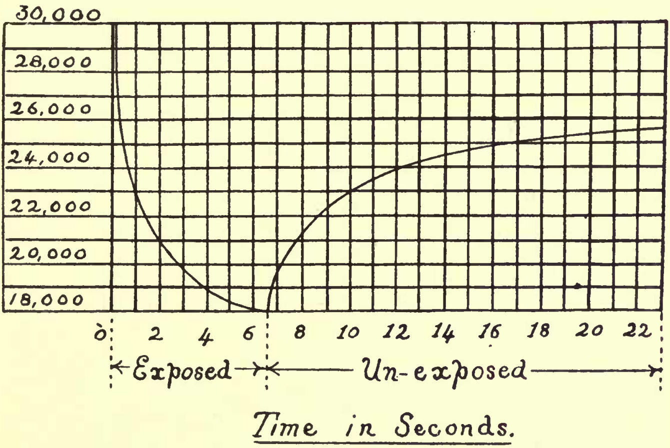


FIG. 14

opaque portion. Instead the inertia interferes, and the resistance only partially rises, causing what should have been a white to be recorded on the receiver as a half-tone. Again, selenium requires to be illuminated for a definite period before it reaches the full resistance value for that amount of illumination to which it is at any instant exposed, so that in order to obtain passable results at the receiving station the rate of transmission has to be fairly slow.

Compensation Devices.

One method of counteracting the inertia or "lag," as it is termed, is that adopted by Prof. Korn of always keeping the cell illuminated sufficiently to overcome it, so that any additional light acts very rapidly. Continued illumination, however, produces a permanent defect in the cells termed

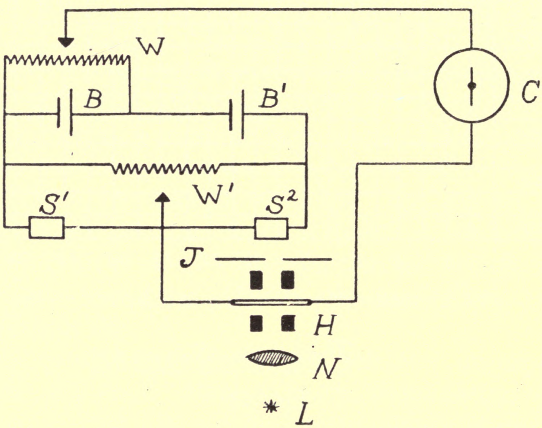


Fig. 15

"fatigue," the cells becoming very sluggish and uncertain in their action, and the ratio of their sensitiveness gradually becoming less; excessive illumination will also produce similar results.

Another method worked out and patented by Prof. Korn, and known as the "compensating cell" method, gives a rapid and practically dead-beat action, the resistance returning to its normal condition as soon as the illumination ceases. The arrangement is given in the diagram Fig. 15. A selenium cell S′ is placed on one arm of a Wheatstone bridge, a second cell S, being placed on the opposite arm. The selenium cell S′ should have great sensitiveness and small inertia, the compensating cell S having small sensitiveness and large inertia. Two 100-volt batteries, B and B′, are connected as shown, being provided with a compensating variable resistance W ; W′ is also a regulating resistance. When no light is falling upon the cell S′, light from the Nernst lamp L is prevented from reaching the second cell S by a small shutter which is fastened to the strings of an Einthoven galvanometer H, and the apparatus C, at the receiving station remains in a normal condition. When, however, light falls upon the cell S′, the balance of the bridge is upset, and light from L falls a fraction of a second later upon the second cell S, and the current flowing through C completes the circuit. Needless to say, it is necessary that the two cells be well matched, as it is very easy to have over compensation in which case the current is brought below zero. It is also stated that by enclosing the cells in exhausted glass tubes their inertia can be greatly reduced and their life considerably prolonged. The life of a cell varies considerably, some remaining in good working order for several months, while others will become useless in a few weeks.

A diagram of the complete transmitting apparatus is given in Fig. 16.

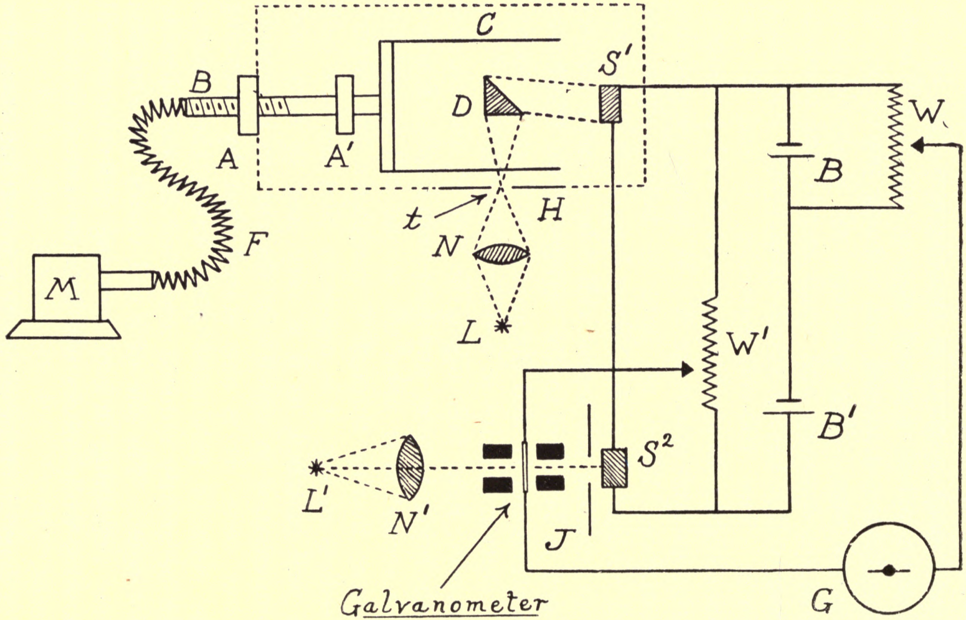


FIG. 16

THE RECEIVER.

Now let us see how this constantly varying current is utilized at the receiving station to reproduce the picture transmitted. A diagram of the receiving arrangements is given in Fig. 17.

It consists of a glass cylinder J, mounted and driven by methods similar to those employed at

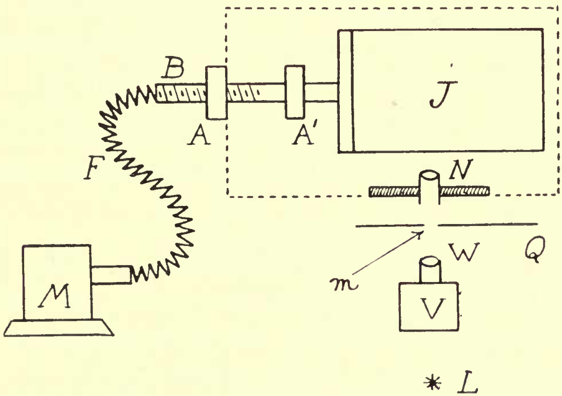


FIG. 17

the transmitting station. In front of this cylinder is placed a screen Q, which contains in the centre a small wedge-shaped aperture *m*. V is a special form of galvanometer containing a small suspended shutter, a shadow of which is thrown by means of the lens W over the triangular aperture *m*, and this shadow, when the shutter is in its normal position, i.e. at rest, prevents light from the lamp L′ from passing through the aperture *m* and reaching the revolving cylinder J.

Under the influence of the varying currents received from the transmitter the shutter of the galvanometer is displaced, causing the shadow to move more or less towards the base of the triangular aperture, allowing light from L′ to pass through the aperture and so reach the sensitized photographic film wrapped round the cylinder J. The lens N is used to concentrate the light passed through the aperture to a small point upon the photographic film. The amount of light projected upon the film depends, therefore, upon the extent to which the galvanometer shutter is displaced, and this in turn is in proportion to the alterations in resistance of the selenium cell at the transmitting station.

The galvanometer V, of the Einthoven type, is essentially a moving coil instrument, being remarkable for its extreme sensitiveness and deadbeat action. The modified form of this galvanometer, as arranged by Prof. Korn, consists of a very powerful electro-magnet, the pole pieces of which converge almost to points. Two very fine silvered quartz threads are stretched between the poles, the tension being adjusted by means of a micrometer screw. By following the well-known rule for the direction of motion of a current-carrying conductor in a magnetic field, it is evident that when current flows through the wires they are displaced in a lateral direction between the pole pieces, as shown by the arrow in Fig. 18 ; the current passing through both wires in the same direction. A tunnel is bored through the pole pieces, and one of them is fitted with an adjustable short focus lens M. The light from L passes through the tunnel, but, as already explained, cannot reach the cylinder through the aperture in Q owing to M throwing a magnified image of the small shutter S over the aperture *m* when the galvanometer is in its normal position. The shutter is of very thin aluminium foil, about

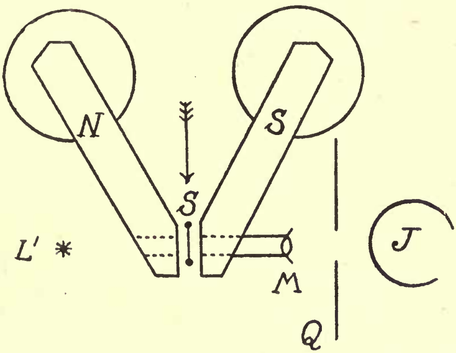


FIG. 18

2 mm. square, attached to the wires at the optical centre.

The wires used are about $\frac{1}{1000}$ of an inch in diameter, and their resistance anything between 2,000 and 10,000 ohms, the length of wires free to swing being usually about 5 cm. In the most sensitive type of these instruments glass or quartz is used for the strings, and these are silvered to give them a conducting coating.

The periodic time of vibration of the wires depends to a great extent upon their length and diameter, and also upon their tension, and by varying these the periodic time can be adjusted between the aperiodic state and $\frac{1}{1200}$ of a second.

The flux density in the gap between the poles must be as high as possible to obtain maximum sensitivity, and the magnet cores must be fully saturated in order that variations in the field current may not affect this flux density, and therefore the sensitivity. Damping is partly electro magnetic and partly due to air friction.

As there is a practical limit to the tension and fineness of the wires, the period can be shortened by using shorter wires, but the current necessary to displace them an equal distance becomes greater, and it is therefore obvious that the resistance of the selenium cell at the transmitting station and the resistance of the line connecting the two stations set a practical limit upon the length of the wires. The best results are obtained when the galvanometer is adjusted to suit the range of current received, the range depending upon the selenium cell used. If the swing of the shutter is too great, a small battery with a regulating resistance can be inserted in the circuit in order to limit the movement, the current flowing in a direction opposite to the line current.

The cylinder at the transmitting end measures 13 cm. long by 7 cm. in diameter, so that the picture transmitted is 22 × 13 cm. while the cylinder at the receiving station is of such a size that the area of the received picture is one quarter the area of the picture transmitted. Both the

Fig. 19

PHOTOGRAPH TRANSMITTED BY PROF. KORN'S SELENIUM MACHINES transmitting and receiving cylinders are enclosed in a light tight box to prevent any extraneous light from reaching the selenium cell and photographic film.

Synchronism.

Synchronism of the two stations is effected in the following manner: The transmitting drum T (Fig. 20) is provided with a projecting pin, which strikes against the contact spring X once in each revolution, causing it to break contact with C and make fresh contact with A. All the time X remains in contact with C, the selenium cell S is in circuit with the line, but when it makes contact with A the selenium cell circuit is broken, and a small fixed resistance V inserted in the line circuit instead. This resistance has a much lower value than that of the selenium cell, so that when this resistance is in circuit a larger current flows to the receiving station.

The receiving drum is provided with a similar pin, which also, once in each revolution, strikes against the contact spring X′, causing it to break contact with *n* and make fresh contact with *m*. All the time X′ remains in contact with *n*, the receiving galvanometer G, is in circuit with the line, but when it makes contact with *m* the galvanometer circuit is broken, and the windings of the relay D inserted in the line circuit instead.

Matters are so arranged that the receiving drum travels slightly quicker than the transmitting drum, and at the end of each revolution the stop L catches against the check K, stopping the movement of the drum, while at the same instant X′ makes contact with *m*, thus throwing the relay D into circuit. The slower moving drum of the transmitter causes X to make contact with A a fraction of a second later than X′, so that the stronger current

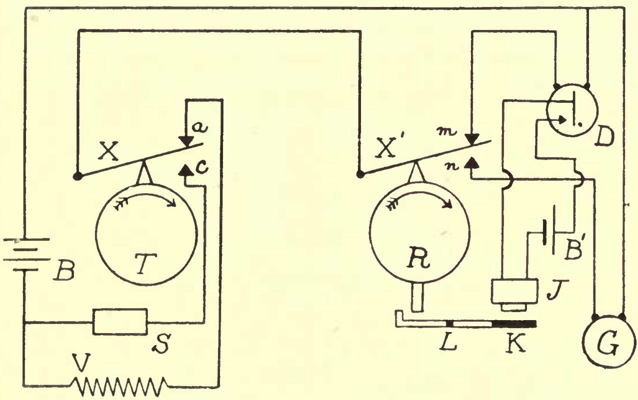


FIG. 20

passing through V flows into the line and actuates the relay D. Upon D becoming magnetized, the local circuit is completed, and current from the battery B′ energizes the magnet J. This attracts a soft iron armature, which is secured to the pivoted check K, withdrawing it from the stop L, allowing the drum R to again start revolving. X then makes contact again with C, and X′ with *n*, both stations then being in normal condition for transmitting and receiving. As the drum R cannot start and stop suddenly at the end of each revolution, a small friction clutch is inserted between the driving motor and the drum R.

The speed of the driving motors is regulated in the following manner: Tappings are taken from the armature, and connected to slip rings, so that an alternating current can be obtained, the motor acting partly as a generator, besides doing good work as a motor in driving the machines. This alternating current is used to operate a frequency

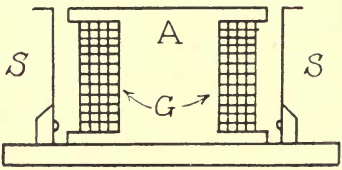


FIG. 21

meter, the principle of which will readily be gathered from Fig. 21. It consists of a circular iron core A, around which is placed the high resistance winding G. Arranged in a circle around the core are a number of thin steel reeds S, which are each tuned to have a different rate of vibration. When traversed by an alternating current the coil G, and therefore the core A, is magnetized and demagnetized many times a second. The tendency is for these reeds to be set in motion, and this happens when the natural frequency of vibration of any of the reeds corresponds with the circuit frequency. By this means the speed of the motors at both stations can be accurately adjusted, the motor speed being varied by means of a field regulator. A diagram giving the connections of the driving arrangements is given in Fig. 22.

APPLICATION.

The selenium machines being practically limited to the transmission of portraits, or very bold subjects,

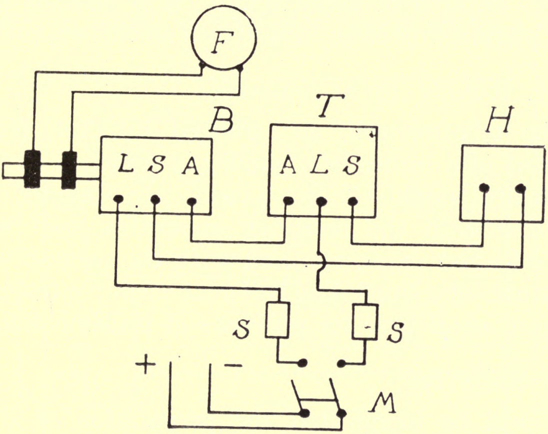


FIG. 22

B—Motor. F—Frequency Meter. H—Field Regulator. M—Main Switch. S—Fuses. T—Shunt Starter.

owing to the comparatively large area of the point of light concentrated upon the negative at the transmitter, it was evident that the transmission of more complicated news pictures would have to be effected in order to make the system of any commercial utility. Attempts were made at one time to send more complicated pictures with the selenium apparatus by enlarging the original and transmitting portions separately, the transmitted portions being afterwards joined together, but experiments in this direction were soon abandoned for reasons that will be explained later.

A photograph measuring $8\frac{1}{2}$ ins. by 5 ins. takes about 12 minutes for the transmission, and as the "point" of light concentrated upon the negative covers an area of about 6 mm., it is obvious that only pictures free of any fine detail can be transmitted.

Prof. Korn's Telautograph.

The telautograph, as arranged by Prof. Korn, consists of a transmitter similar in principle to that originally employed by Caselli (see Chapter II), together with the receiving apparatus used with the selenium machines, and using the suggestion of Amstutz, of a single line half-tone negative fastened upon a metal base for purposes of transmission.

The Negative.

It will be found that the preparation of these line negatives is somewhat similar to the method employed in making the half-tone negatives for the Electrograph (see Chapter III), but the "cross screen" used in the American system is replaced in the present instance by a single line screen, which has the effect of breaking the picture up into bands instead of dots. From this line negative a print is taken off upon a specially prepared sheet of metal, which consists of a sheet of thick lead or tinfoil, coated upon one side with a thin film of fish glue to which bichromate of potash has been added; the bichromate possessing the property of rendering the glue waterproof when acted upon by light. After printing, the metal print is washed under running water, when all those parts not acted upon by light, i.e. the parts between the lines, are washed away, leaving the bare metal. The print now consists of an image composed of numerous bands of insulation separated by a band

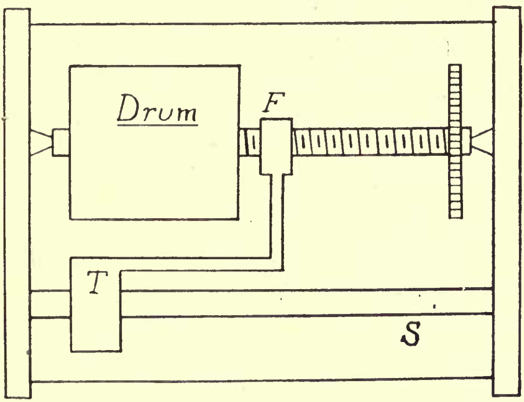


FIG. 23

of conducting material, the bands varying in width according to the density of the photograph at any point from which it is prepared.

TRANSMISSION.

In transmitting, this metal print is wrapped round the drum of a machine constructed on the principle shown in the diagram (Fig. 23). It consists of a metal drum mounted upon a steel shaft, which runs between two hardened steel centres. This shaft has a fine thread cut along part of its length. A small table T, capable of sliding over the bar S, is fitted with an arm carrying at the end a half-nut F, which rests upon the threaded portion of the shaft. A metal stylus, well insulated from the rest of the machine, is fastened upon the table T, and is arranged to press upon the metal print wrapped round the drum. As the machine revolves a lateral movement is given to the table by reason of the screwed shaft

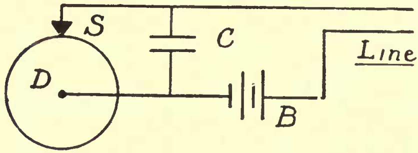


FIG. 24

and half-nut, causing the stylus to trace a spiral path over the entire surface of the print. The electrical connections are given in Fig. 24.

As the stylus S traces over a conducting strip on the metal print the circuit is completed, and a brief current is sent through the line to the receiving station, but which is stopped on the stylus passing over a strip of insulation. The function of this transmitter is therefore to send out an intermittent current of varying duration, the duration depending upon the width of the conducting strip that is passing under the stylus at any instant.

THE RECEIVING APPARATUS.

The receiver designed to work with this form of transmitter is a modification of the receiver used with the selenium machines and is shown in Fig. 9. The arrangement of the receiving apparatus is given in the diagram (Fig. 26).

FIG. 25

SPECIMEN OF TELAUTOGRAPH WORK

Round the receiving drum C is wrapped a sensitized photographic film, the drum being enclosed in a light tight box to exclude all extraneous light. In the centre of one side of the dark box an adjustable lens Z is fitted, and this lens concentrates to a fine point upon the drum C all the light that is passed by the scource of light T through a fine slit in the screen J. Situated between the lamp T and the screen J is a galvanometer of the Einthoven type, the two fine threads of which have been

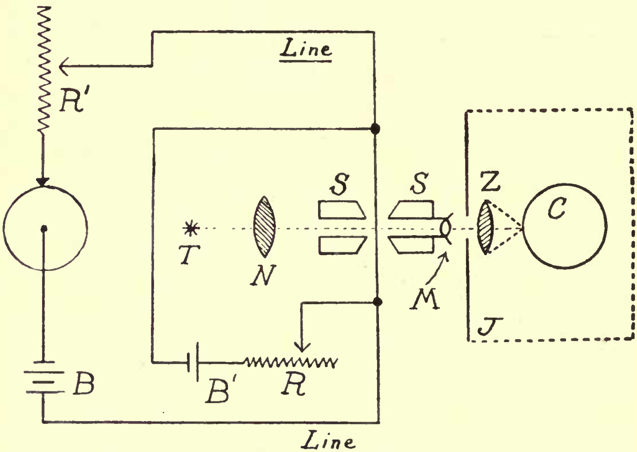


FIG. 26

replaced by a single flat silver wire. A shadow of this wire is thrown over the slit in J, when the galvanometer S is in its normal position, i.e. at rest, and when in this condition no light from T can reach the drum C.

Under the influence of the line currents this wire is displaced laterally, and the shadow moves to one side on the screen J, uncovering the slit and allowing light from the lamp to reach the drum.

The shadow of the galvanometer wire is sharply focused over the slit in J, by means of a short focus lens M, fitted into a hole bored through the pole pieces of the galvanometer.

By using a single wire thread in the galvanometer, the instrument is practically similar to that originally designed by Prof. Einthoven, except that he employed a single silvered quartz or glass thread in place of the flat silver wire. In the most sensitive instruments the quartz thread is only 0·002 mm. (0·08 mil.) in diameter, and in the commercial instruments a thread of this diameter when viewed through the microscope is displaced 6 mm. with one microampere ($\frac{1}{1,000,000}$), and one 1 mm. deflection has been obtained with a current as small as 10^{-12} ampere (or, one-trillionth of an ampere). By adjusting the tension the period of swing can be reduced to $\frac{1}{1,200}$ of a second, but at high tension, however, the instrument ceases to be dead beat, while if the thread is too slack it takes several seconds to obtain full displacement, moves out of focus when displaced, and becomes uncertain in zero.

As already mentioned, the driving mechanism is similar to that employed with the selenium apparatus, but as the transmitted currents are greater with the telautograph than with the selenium machines, a somewhat different system of synchronizing the two stations is employed.

How Synchronism is Obtained.

By means of field regulators ard frequency meters, the speeds of the driving motors at both stations are adjusted so that the receiving drum is revolved about 1 per cent. faster than the transmitting drum. The arrangement at the receiving station for checking the rotation of the drum, and switching the galvanometer out of circuit, is practically identical with that described for use with the selenium machines and illustrated in Fig. 20, the only difference being that the relay D is replaced with a sensitive polarized relay. At the transmitting station the line wires are connected to the terminals F,F of a current reverser, the four contact studs of the reverser being connected as shown in Fig. 27.

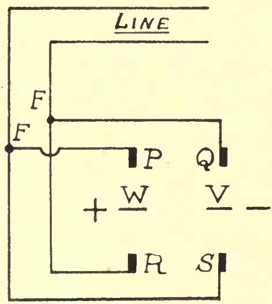


FIG. 27

A fraction of a second after the galvanometer at the receiving station has been thrown out of circuit and the polarized relay switched in, the pin A on the transmitting drum (Fig. 28) has reached such a position that it presses down the bar D, which is pivoted at T. At one end of this bar is fastened a flat insulating plate which carries two contact springs W,V, the spring V being connected to the stylus S, and the spring W to the positive pole of the battery B. For nearly the whole of the time of each revolution, the springs W,V are in contact with the studs R,S, and current flows in one direction to the receiving station, but for the short period that the pin A depresses D the springs W,V break contact with R,S and make fresh contact with studs P,Q, reversing the current flowing through the line. As the relay at the receiving station is polarized and only sensitive to currents flowing in one direction, it is actuated by this reverse current and the local circuit is completed, allowing current from B′ (Fig. 20) to energize

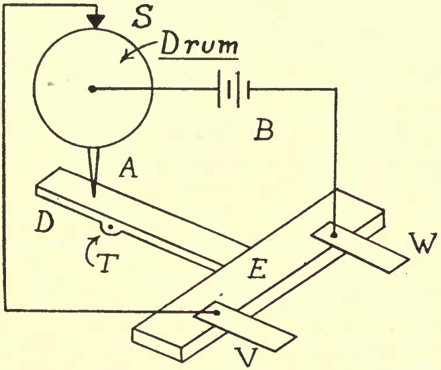


FIG. 28

the magnet J, which attracts the armature K, thus releasing the stop L. The two machines thus start each revolution in perfect synchronism.

In Fig. 26 it will be noticed that a regulating resistance R, in series with a battery B′, is shunted across the galvanometer string, and this is so adjusted that a small displacement is given to the string opposite in direction to that caused by the line current. If the received current is more than that required to just uncover the slit in J, the necessary amount of extra line resistance can be inserted by means of R′. By this means the movement of the string is readily controlled, either to work with a received current of any strength, or with any width of slit in J.

The diameter of the transmitting drum is about 2·5 ins. diameter and 7 ins. long, and by using a single line screen ruled 40 to the inch to prepare the metal print, the stylus will have to make about 300 contacts during one revolution (the drum is revolved once in two seconds), or 150 per second. At this speed, if the distance between the two stations is such as to necessitate the use of a fairly heavy current for transmitting, sparking is apt to take place at the stylus at each make and break, and this, if excessive, will gradually burn away the point of the stylus. It can be practically obviated by connecting a small condenser (about 1 microfarad capacity) across the drum and stylus, as shown in Fig. 24, but to a great extent the sparking is due to the self-induction of the line.

Experimental Machinery.

The writer, when first experimenting with this system of photo-telegraphy, endeavoured to make the receiving apparatus self-contained, and Figs. 29 to 31 show one idea that was worked out, but after making several trials which proved its unsuitability and obtaining some interesting data, experiments were continued along other lines.

The machine used was one specially built by the writer for experimental work, and the same type of machine was used for both transmitting and receiving. This machine, without driving or synchronizing gear, is illustrated in the photograph (Fig. 33). The electric lamp L is about 8 c.p., and is placed just within the focus of a lens having a focal length of $\frac{3}{4}$ in. When a source of light is placed at the principal focus of a lens, the light rays are not converged but are transmitted in a parallel beam the same size as the lens. It has been found that this arrangement gives a line on the drum more sharply defined than would be the case were the light focused direct upon the hole in the cone A. An enlarged drawing of this cone is given in Fig 30. The hole in the top of the cone is a bare $\frac{1}{90}$ in. in diameter—the size of this hole obviously depends upon the travel per revolution of the table of the machine—and in working, the cone is run as close as possible to the drum without being in actual contact. The magnet M is wound with No. 40 s.s.c. wire to a suitable resistance, and the armature is made as light as possible. The

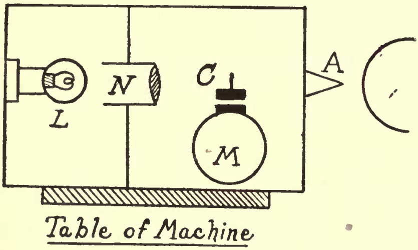


FIG. 29

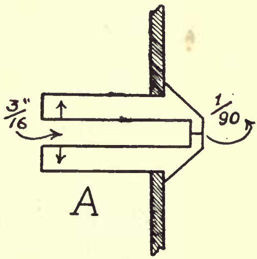


FIG. 30

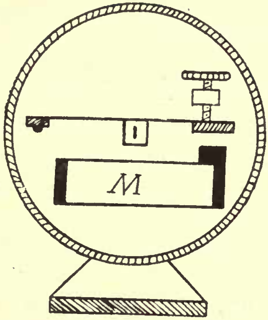


Fig. 31

Fig. 32

SPECIMEN OF TELAUTOGRAPH WORK

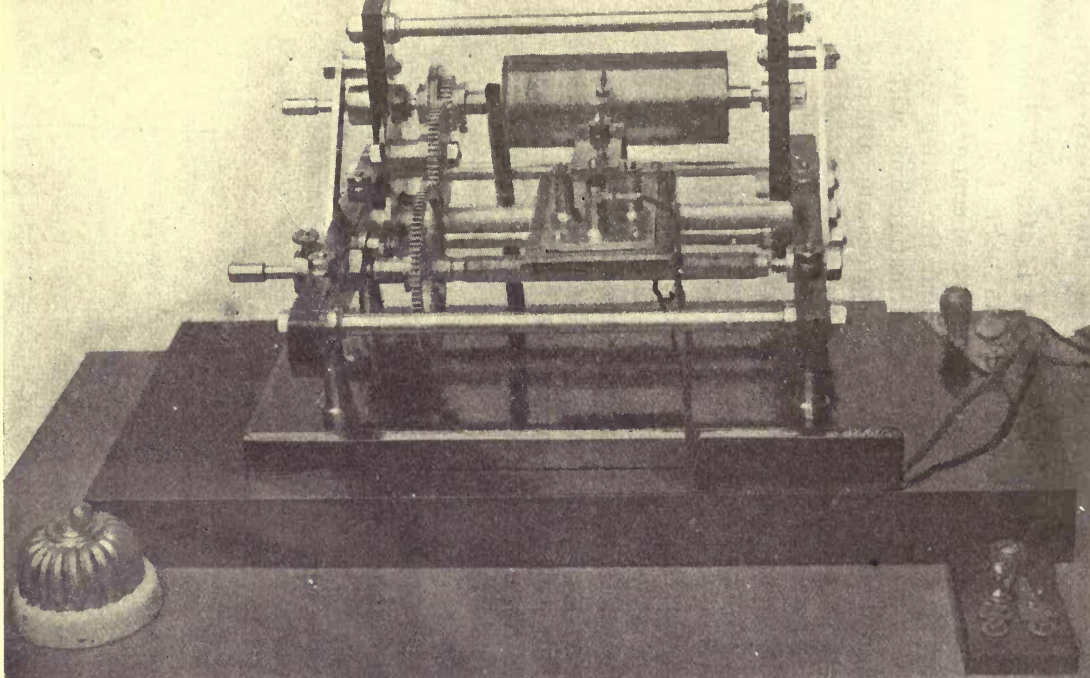


Fig. 33

PHOTOGRAPH OF AUTHOR'S EXPERIMENTAL MACHINE spring to which the armature is attached should be of such a length that its natural period of vibration is equal to the number of contacts made by the transmitting stylus, and the spring must be stiff enough to bring the armature back with a fairly crisp movement. The springs and armature are shown separately in Fig. 31.

The shutter C is $\frac{1}{4}$ in. square and made of very thin aluminium. The hole in the centre is $\frac{1}{16}$ by $\frac{1}{8}$ of an inch, and the movement of the armature is limited to about $\frac{3}{32}$ in. In all arrangements of this kind there is a tendency for the armature spring to vibrate, as it were, sinusoidally, if the coil is magnetized and demagnetized at a higher rate than the natural period of vibration of the spring. This causes an irregularity in the rate of the vibrations, which affects the received image very considerably.

This arrangement will work fairly well over short-line distances, but its action is rather coarse. It can, however, be made sensitive enough to work at a speed of 1,000 to 1,500 contacts per minute, with a current of ·5 milliampere.

CHAPTER V

PROF. BELIN'S TELESTEREOGRAPH

THE idea of using a photograph in relief to vary the resistance of an electrical circuit was first suggested for purposes of photo-telegraphic transmission by Amstutz, one of the early workers, and this idea has been followed up by Prof. Belin, a French scientist, with great success.

ARRANGEMENT OF THE APPARATUS.

The first transmitting arrangements of Prof. Belin's apparatus, which he has designated the telestereograph, consisted of a revolving metal drum V (Fig. 34), round which is wrapped a photograph in relief. An arm pivoted at E carries at one end a hardened steel stylus S, and at the other end a small platinum wheel O which is free to revolve. This wheel runs over the segments of a small rheostat R, which consists of a number of copper strips separated by an insulating medium, one surface being worked smooth to the circumference of a circle taking the centre at the point E, the radius being EO. Coils of different resistances are fastened at one end to the copper strips, the other ends being connected together. A connection is taken from one terminal of the battery B to one terminal of the rheostat R, and from the other battery terminal to the line, the stylus S being connected to the remaining line terminal.

As the stylus traces a path over the surface of the drum it is raised or lowered according to the amount of relief on the photograph, and as the stylus moves over the relief the wheel O, at the other end of the rod, is also moved in a proportionate manner over the surface of the rheostat, thus varying the resistance of the circuit. The photograph in relief used for transmitting is really a print made upon what is termed carbon tissue, which consists of a sheet of paper coated upon one side with a bichromated solution of gum, the bichromate rendering the solution sensitive to light.

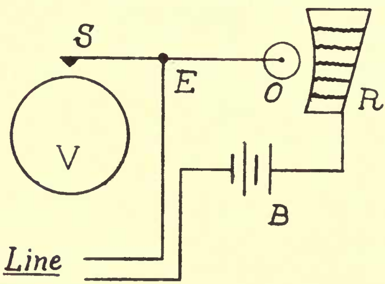


Fig. 34

In taking off a print upon this tissue from an ordinary negative the light acting upon the tissue varies according to the density, thereby rendering the bichromate in the solution more or less insoluble. Upon "development" in hot water the surface of the gelatine is washed away to a depth proportional to the intensity of the light to which it has been exposed. For pictorial photography the bichromated solution is coloured by means of any desired pigment in a finely powdered condition, and as the tissue is washed away according to the density of the negative used in preparing it, so the white paper background shows more or less through the tissue giving the fine graduations in tone associated with the process. A greatly enlarged transverse section of a relief photograph is given in Fig. 35, in which the portion A represents the high lights, B the half-tones, and C the shadows on the negative

At the receiving station the line is directly connected to the terminals of a Blondel oscillograph G, which consists of two very fine silver wires

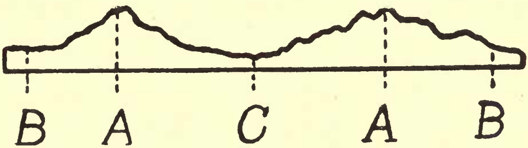


FIG. 35

stretched across the field of a powerful electromagnet. In this instrument the current passes down one string and up the other, and not through both of them in the same direction, as in the Einthoven galvanometer. At the centre of these wires is attached a small, very light mirror M (Fig. 36), and this mirror, together with the wires, is twisted, the amount of twist depending upon the intensity of the current passed through the instrument. The current sent out from the transmitter is practically continuous, as the wheel O is always in contact with at least two of the rheostat segments, so that as the change in intensity of the current is gradual, the reduced sensitiveness of the oscillograph due to damping is not so important as would be the case were the transmitted currents periodic, as in Korn's telautograph.

Light from a source L is projected upon the mirror M, which in its turn reflects it upon a narrow rectangular aperture in the screen J. Over this aperture is fastened a "scale of tints," which is a strip of photographic film graduating from full to no exposure, so that as the mirror of the galvanometer G oscillates under the influence of the

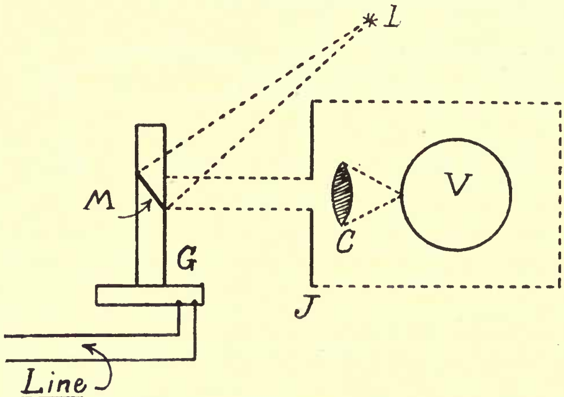


FIG. 36

varying received current, the spot of light reflected by M travels to and fro over this scale, allowing more or less light to be concentrated by the lens C upon a sensitive photographic film wrapped round the drum V of the machine.

It has been remarked that the method of damping employed reduced the sensitiveness of the instrument, but increased sensitiveness could be obtained by using a stronger magnetic field and longer wires for the suspension, but in this case a longer period of swing would be obtained and hence a slower speed of working. In its most sensitive form only a very small current is required to produce a movement of the mirror, while in some instances it is hardly visible to the naked eye. The ray of light reflected from the mirror really can be regarded as a long weightless pointer, and the angle of reflection is, according to the well known laws of light, double the angle through which the mirror is turned, so that a very small movement of the mirror will produce an appreciable movement of the spot of light over the aperture in the screen; the movement of the spot of light can be regulated by altering the distance between the mirror and the screen. The movement of the mirror, and therefore the spot of light, is practically proportional to the current and inversely to the relief of the photographic print used for transmitting. As the transmitting and receiving machines, together with the driving and synchronizing arrangements, are practically identical with what has already been described in dealing with Prof. Korn's system, there is no need to recount them.

The arrangement just described proved useless for commercial work, and was soon discarded, as the preparation of a carbon print in which the relief is very pronounced is a long and difficult operation, besides which, the employment of a rheostat to transform the reliefs of the carbon print resulted in the received picture being shaded in steps instead of an infinite variety of graduated shading, and by arranging the wheel O to make contact with more than two rheostat segments a certain amount of necessary detail is lost.

ANOTHER FORM.

The moving wheel and rheostat at first employed for altering the resistance of the circuit has now

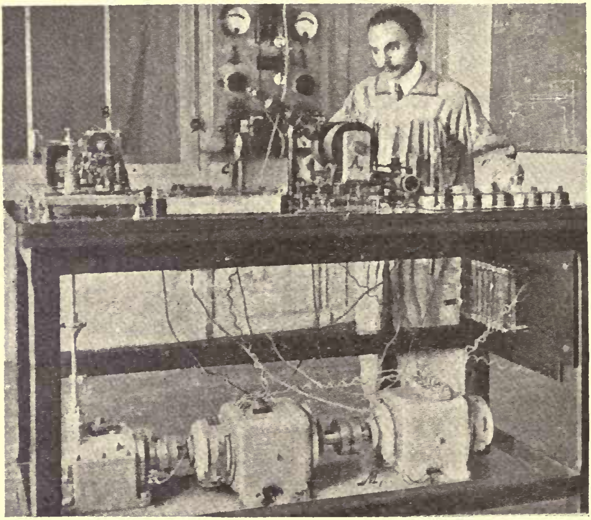


FIG. 37
PHOTOGRAPH OF PROF. BELIN'S APPARATUS

been replaced by a special form of microphone, the stylus being arranged to press upon the diaphragm. The microphone used is a large form of one of the early types, in which the movement of the diaphragm alters the presssure upon three carbon balls, varying their resistance, and consequently the strength of the current flowing through the circuit. With this form of transmitter the carbon print is made upon very thin tissue, much easier and quicker to prepare, in which the graduations in relief are very minute, this being necessary as the range of movement of the microphone diaphragm is very limited, even with the large type of microphone under discussion, the movement of an ordinary microphone diaphragm, measured at the centre, being between 10^{-4} cm. and 10^{-6} cm.

Excellent as were the results obtained with this apparatus, the distance over which effective transmission could be maintained was not very great. To overcome this difficulty the " rheomicrophone " was invented by M. Belin in 1912, and some good results were transmitted between Havre and Paris, Bordeaux and Paris.

The Rheomicrophone.

This was so named because it combines the qualities of the rheostat and the microphone. It consists of an alternator of 600 periods connected in series with a special microphone and the primary of a transformer, the secondary being connected to the line. At the receiving station the secondary of the transformer is again connected to the line, the primary being connected to the oscillograph.

Experts state that in the experiments made between Bordeaux and Paris, this being a distance of about 350 miles, the sharpness and value of the original impressions remained perfect. A photograph of M. Belin's latest apparatus is given in Fig. 37.

CHAPTER VI

THE TELECTROGRAPH

This system of photo-telegraphy, which is based on the principle first suggested and tried by Bain (1842) and Bakewell (1847), for the transmission of writing and printed matter, has been developed by Mr. T. Thorne-Baker to such an extent that at the present time it is the simplest and the most efficient system that, as yet, has been devised for transmission over metallic conductors.

The chief advantages are that the picture is visible during the whole of the receiving, and that by very simple regulation the various conditions of the line encountered in working can be counter-balanced and overcome.

In the telectrograph we have once again similar transmitting arrangements to those already described in connection with the telautograph of Prof. Korn, in which a Caselli transmitter is employed together with a single line glue image upon a metal base. The machines used both for transmitting and receiving are also similar in principle to what has already been described and illustrated in the diagrams (Figs. 23 and 24).

The Receiving Apparatus.

This is a modification of the chemical telautograph of Bakewell, in which a sheet of paper saturated in a chemical solution is wrapped round the drum of the receiving machine, the chemicals being decomposed on the passage of an electric current through them, producing a coloured mark.

In the telectrograph, the image is reproduced on the chemical paper as a number of coloured marks of varying lengths, these marks corresponding to the conducting strips on the metal prints, which vary in width according to the density of the photograph from which it is prepared. The paper used has to be very carefully chosen, as besides being absorbent enough to remain moist during the whole of the receiving, the surface must also remain fairly smooth, as with a rough grained paper if there is any excess of solution the marks are inclined to spread and so cause a blurred image. The paper is soaked in a solution consisting of—

Ferrocyanide of Potassium, $\frac{1}{4}$ oz.
Ammonic Nitrate, $\frac{1}{2}$ oz.
Distilled Water, 4 oz.

About 1 milliampere of current is required to decompose the solution in the paper, and the resistance of the paper may be anything from 1,000 to 3,000 ohms. The paper must therefore be kept in a moist conducting condition during reception, as if it gets too dry the resistance becomes excessive, causing very faint marking.

Transmission.

The size of the metal print used for transmitting is about 7 ins. by 5 ins., and if a screen having 50 lines to the inch is used to prepare it the stylus will have to make 350 contacts in one revolution, and as the machine is revolved once in two seconds, the stylus makes 175 contacts per second or 10,500 contacts per minute. The chemical action that takes place during electrolysis is very small, as the intermittent current sent out from the transmitter in some instances only lasts from $\frac{1}{100}$ to $\frac{1}{50}$ of a second. The quantity of an element liberated is by weight, the product of time, current, and the electro-chemical equivalent of that element, and is given by the equation, W = z, c, t, where

W = quantity of element liberated in grammes,
z = electro-chemical equivalent,
c = current in amperes,
t = time in seconds.

SPEED OF WORKING.

The absence of mechanical and electro-magnetic inertia enables this type of receiver to record signals at a very high speed. The effects of capacity and inductance—properties inherent to all telegraph systems using metallic conductors—have a distinct bearing upon the two questions, how far and how quickly can photographs be transmitted. Over a very short line, where the capacity effects are small, the signals can be recorded by the telectrograph at a speed of over 200 a second, but with an increase in the capacity of the line this speed soon decreases, and the overcoming of the effects of this line capacity is a problem that still awaits a really practical solution.

When a brief current is sent through a line of considerable length, part of the current is abstracted, and this accumulates upon the surface of the wire in the same manner that a charge is retained upon the coatings of a Leydon jar. This property of absorbing a portion of a current is known, as the electrostatic capacity of a line, its effect, as is well known in telegraphy, being to retard the flow of the current. The accumulated charge in the line makes itself manifest in an extra current, a portion of which flows out of the receiving end of the line and a portion at the transmitting end. This extra current or "secondary discharge," as it is called, is probably one cause of the excessive sparking that takes place occasionally between the point of the stylus and the metal print on the transmitting machine, while at the receiver the effect of this extra current is to prolong the time of discharge, and in the case of the telectrograph causes a longer electrolytic mark to be made than is really required.

The effect of capacity upon an intermittent current is clearly shown in Fig. 38. If we were to send twenty brief currents over a line of moderate capacity in a given time, we should find that instead of being recorded separately and distinctly as at *a*, each mark would be pointed at both ends and joined together as shown at *b*, while only perhaps fifteen could be recorded. If the capacity be still further increased, as at *c*, only perhaps half the original number of currents could be recorded in the same time, owing to the fact that with an increase of resistance, capacity, and inductance of the line a longer time is required for it to charge up and discharge, thereby materially reducing the rate at which it will allow separate signals to pass; the number of signals that can therefore be recorded in a given time is greatly diminished. If we were to attempt to send the same number of signals over a line of great capacity as could be sent, and recorded separately and distinctly over a line of small capacity—the time limit being the same in both instances—we should find that the signals would be recorded practically as a

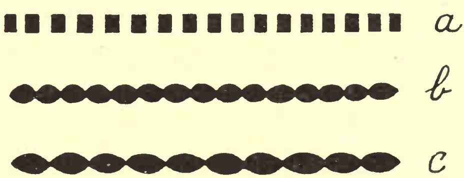


Fig. 38

continuous line. The two latter cases, *b* and *c* (Fig. 38), clearly shows the retardation that takes place at the commencement of a current and the prolongation that takes place at the finish.

The quantity of electricity accumulated upon the surface of the wire depends upon the length and diameter of the wire, its distance from the earth, and the insulating medium surrounding the conductor. In the case of an overhead line, although this is suspended a good distance above the earth with air as a dielectric, yet, as it is more or less in contact with earth connected bodies, it is able to retain a charge. With a submarine cable in which the conductors are insulated with india-rubber, and placed in close proximity to the earth, a much larger charge is retained by the wire. It has been found that the electrostatic capacity of one mile of submarine cable, insulated with rubber, is equal to the capacity of 20 miles of overhead line, and as the effect of capacity is to reduce the rate at which it will allow separate signals to pass, it is evident that where there is any great length of submarine cable in the circuit the speed of possible working is enormously reduced.

If we take for an example the London-Paris telephone line, with a length of 311 miles and a capacity of 10·62 microfarads, we find that about half this capacity, or 5·9 microfarads, is contributed by the 23 miles of cable connecting England with France. These measurements, however, only apply to a single line, as where a double line is employed the capacity is halved. On a cable joining this country with America the current is retarded four-tenths of a second. Since cables possess the largest capacity it is their position in the circuit that has the greatest effect upon the conditions of working. The capacity of a single overhead line can be calculated from the equation—

$$C = \frac{1 \times 2 \cdot 415 \times 10^6}{\log 10 \frac{4H}{d}}$$

where d equals the diameter, 1 the length, and H, the height above ground.

In photo-telegraphy the reduction of speed due to capacity has, to a great extent, been overcome by means of apparatus known as a line balancer, which, in principle, is somewhat similar to the compensating circuit employed in duplex telegraphy. In telegraphy the use of a reverse current is well known, as it hastens the slow discharge of the line and increases the possible rate of working, allowing the intermittent signals sent out from the transmitter to be recorded separately on the receiver.

A diagram of the balancer is given in Fig. 39.

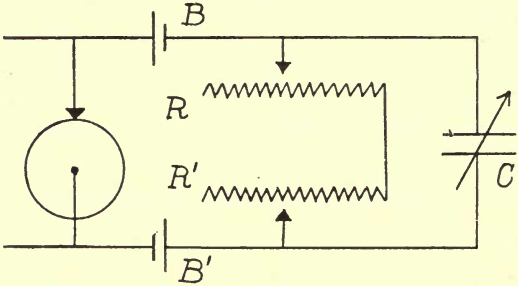


FIG. 39

As will be seen from the figure, the line is connected to the balancer circuit, which comprises two batteries B,B′, two variable resistances R,R′, one end of each resistance being joined together. The sliding contacts of the resistances are connected by a variable condenser C, of about 1 microfarad capacity. By regulating the various elements the varying line conditions can be counterbalanced, and the operator can ensure the received signals being absolutely sharp and distinct.

Capacity also introduces induction, and this helps to counteract the distortion of the signals due to capacity. Induction is, however, more noticeable in overhead lines than in cables, because in the latter the lines are close together, and, the current flowing through the two lines in opposite directions, the self-induction is partly neutralized. If in any circuit the capacity and induction are equal they neutralize each other and the current is distortionless, hence in long distance transmission extra inductance is included in the circuit by means of loading coils. In practice, for photo-telegraphic work, telephone lines are preferable, as with the small currents used, and to prevent interference from earth currents, it is necessary to provide a complete metallic circuit. In telephony the distortion of the current due to capacity is given by the equation—

$$D = \frac{R}{2L} - \frac{S}{2K}$$

where R is resistance, L inductance, S leakance, and K capacity.

Where a line is supported at regular intervals, and particularly in damp or wet weather, the accumulated charge partially leaks away through the moisture collected on the insulators. This is known as the "leakance" of a circuit, and its effect is to obstruct the charging up of the line.

From the foregoing remarks and a study of Fig. 39, it is easy to see how simple the telectrograph is for commercial work. By means of the balancer adjustments to suit all line conditions met with in working can very easily be made. In wet weather it has been found that less balancing is required than in dry weather. The greater the capacity of the line the more the balancing capacity that must be added by means of C, and the greater the distortion of the signals, or the elongation of the electrolytic marks made on the receiver, the less the resistance added to the circuit by means of R,R′. With a photographic method of reception all the adjustments must necessarily be made beforehand, any error not being discovered until the photograph has been received and developed, whereas with the telectrograph the adjustments can be made when working and any error corrected before any important portion of the photograph has been received.

It has already been mentioned that great care must be exercised in choosing the paper for receiving. No special means are required for fastening the paper to the drum, the moist paper adhering quite firmly. Care should be taken, however, to fasten the paper—which should be long enough to allow for a lap of about $\frac{1}{4}$ in.—in such a manner that when working the stylus draws away from the edge of the lap and not towards it.

All that has been written with regard to the effect of the line conditions on the working of the electrolytic receiver applies more or less to the various other systems that have been described. It is only a favoured few who can work over an actual telephone line and so be able to carry out their experiments under natural conditions, but very good work can be done on an artificial line, the varying factors such as capacity, inductance, resistance, etc., being easily arranged to suit any special conditions it is desired to work under. By this method a lot of useful experimental work may be undertaken, and various methods for overcoming line faults tried and tested.

The quality of the received image is also largely affected by the metal prints used for transmitting, and these require very careful preparation if the best results are to be obtained. It is evident that the metal print used will be a positive, since it is prepared from a negative. As a chemical mark is produced every time the transmitting stylus traces over a conducting strip, it is evident that the received picture will be a negative one, and, if it is to be used for newspaper work, making the final reproduction a negative one also. This is no good. The final reproduction must be a positive, therefore the received picture must also be a positive. This is arranged for as shown in Fig. 39. By means of the battery B a current is constantly flowing through the electrolytic paper, producing a coloured mark all the time the transmitting stylus is tracing over an insulating portion of the metal print. When tracing over a conducting portion a current flows from the sending battery which, being in a direction opposite to the continuous current, neutralizes it and prevents it from making an electrolytic mark; the continuous current wiping out the transmitter current as soon as it has ceased to flow. As explained elsewhere, the use of a double current system of working is well known in telegraphy, hastening the slow discharge of the line and thereby increasing the number of signals that can be transmitted in a given time.

These precautions are not necessary with any photographic method of reception, as it is very easy to so arrange matters at the receiver that the film is kept permanently illuminated while the stylus on the transmitter is tracing over an insulating strip, and in darkness when tracing over a conducting strip.

With the telectrograph the decomposed marks on the paper are blue, and, as photographers know, blue is reproduced in a photograph as a white, so that a photograph taken of an electrolytic picture, which will of course be a blue image upon a white ground, will be reproduced almost like a blank sheet of paper. If, however, a yellow contrast filter is placed in front of the camera lens, and an orthochromatic plate used, the blue will be reproduced in the photograph as a dead black.

It is necessary to connect the stylus of the receiving machine to the positive pole of the battery, otherwise the electrolytic marks will be made on the underside of the paper.

CHAPTER VII

MISCELLANEOUS DETAILS

THE varying conditions of the line mentioned in the last chapter, with regard to the working of the telectrograph, also apply, in a greater or lesser degree, to all the other systems described, the distortion effects being, however, more pronounced when intermittent currents of varying duration are being transmitted. The speed of transmission and the quality of the received picture is, in any photographic method of reception, dependent upon other factors than the line conditions: the nature of the source of light used, and the chemical inertia of the photographic film, both playing an important part in the successful reproduction of the picture.

LIGHT SOURCES FOR RECEIVING APPARATUS.

In all the photographic methods of reception that have been described no mention has been made of any special source of light for illuminating the sensitive film, but in nearly all photo-telegraphic experiments up to the present a Nernst lamp has been invariably employed. As the length of exposure during reception is very short it is essential that the source of light should possess a high actinic power, and although since the introduction of the high-voltage metal filament lamps the Nernst lamp has been more or less discarded for commercial purposes, yet, since it produces abundantly the blue and violet rays which have the greatest chemical effect upon a photographic plate or film, it is from a photographic point of view, eminently suitable for the purpose under discussion. These rays are known as chemical, or actinic rays, and are only slightly produced in some types of incandescent electric lamps. Because a light is visually brilliant it must by no means be assumed that it is the best to use for purposes of photography. Many sources of light while excellent for illumination have very low actinic powers, while others may have low illuminating but high actinic powers. A light yellowish in colour has usually low actinic power, while all those lamps giving a soft white light are generally found to be highly actinic. The actinic value of the light produced by means of a carbon filament lamp is very low. The following table of several sources of illumination arranged according to their actinic value is appended, together with the current consumption and the intrinsic brilliancy (c.p. square in.)—

Type of Lamp.	Watts per c.p.	Intrinsic Brilliancy.
Enclosed arc . .	0·45	20,000
Nernst lamp . .	1·5	1,000–2,500
Incandescent gas mantle	—	20–35
Metallic filament . .	0·5–2·0	1,000–1,200
Carbon filament . .	3·3	300–500

The Nernst lamp depends for its principle upon the discovery made by Prof. Nernst, the inventor of the lamp, in 1898, that filaments of an infusible earth made from the oxides of several rare minerals, of which zirconia is one, were practically a non-conductor when cold, but when raised to a red heat became a conductor sufficiently well to pass a current which raised it to a white heat, and also that the glowing filament emitted a brighter light

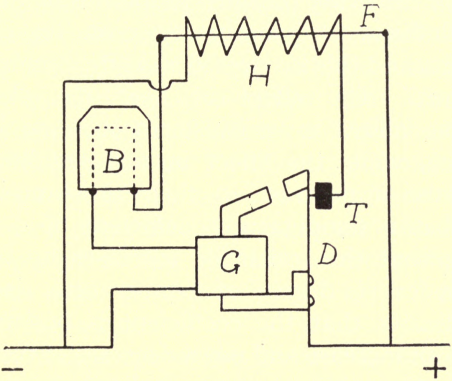


FIG. 40

for a given amount of current than carbon or metal filaments.

The principal parts of a Nernst lamp consist of the heater, the filament, the automatic cut-out, and the ballasting resistance. The electrical arrangement is given in Fig. 40. The action is as follows: The current enters at the positive terminal, passes through the heater H, and out through the negative terminal. As soon as the filament F has been raised to a sufficiently high temperature by means of the heater, it becomes a conductor, and the current then passes through the cut-out C, the armature D being drawn away from the stop T, thus breaking the heater circuit, and this condition is maintained as long as the lamp is kept burning. The current then flows from the positive terminal through the cut-out C, resistance B, filament F, and out through the negative terminal.

Among the many physical properties of a material is the influence of temperature on its electrical resistance, and this is referred to as its "temperature coefficient." The effect of heat on all metals and some alloys is to cause an increase in their resistance, while the effect in non-metallic bodies is to cause a decrease in their resistance. Thus copper has a temperature coefficient of + 0·0038, meaning that the resistance increases by 0·38 per cent. for every degree of temperature rise. The sign indicates that the coefficient is positive, and refers to an increase and not a decrease of resistance. Those bodies whose resistance diminishes as they get hotter are stated to have a negative temperature coefficient, and of solid bodies carbon is a well known example. This negative coefficient of carbon causes the carbon filament lamp, whose resistance is greater cold than when hot, to be very sensitive to changes in voltage, as an increase of voltage causes a decrease of resistance owing to the extra heat generated, and more current is allowed to pass. For this reason lamps should always be connected to the supply-pressure for which they are intended. Metal filament lamps, owing to their possession of a positive temperature coefficient, burn with greater stability as they are not so sensitive to changes in voltage, and therefore do not give such an exaggerated variation in light intensity.

The Nernst filament is, however, much more sensitive to voltage variation as it possesses a much larger negative temperature coefficient, and if used by itself, even on a circuit of perfectly constant voltage, would rapidly destroy itself. It is therefore necessary to insert in series with the filament a conductor having a large positive temperature coefficient, so arranged that the current passes first through this before reaching the filament. Such a conductor or " ballast resistance," as it is termed, consists of a spiral of fine iron wire which, when raised to a dull red heat, to prevent oxidation from exposure to the air, and for easy dissipation of excess heat, is enclosed in a glass bulb filled with hydrogen gas.

Nernst lamps are made in two sizes, the larger being intended for the same work as usually done by arc lamps, and the smaller to replace incandescent lamps, being made to fit into the ordinary bayonet lampholders. Either direct or alternating current can be used with these lamps, and with direct current the polarity must be strictly observed, and that the positive wire is connected to the positive and the negative wire to the negative terminal. With the smaller type of lamp, once it has been correctly placed in its holder with regard to the polarity, it is essential that it should not be turned, as a change in the direction of the current will rapidly destroy the filament.

It is important that the voltage required by the burner and resistance equals the voltage of the supply circuit, and that only parts of the same amperage are used together on the same lamp. In one of the large type of lamps for use on a 235-volt circuit the burner takes 0·5 ampere at 215 volts, and the resistance 0·5 ampere at 20 volts, while one of the smaller type of lamps for use on the same circuit takes 0·25 ampere at 215 volts and 0·25 ampere at 20 volts for the burner and heater respectively. These lamps burn in air and emit a brilliant white light of remarkable steadiness. They can be obtained to suit all voltages from 100 to 300. A photograph of one of the large vertical type of Nernst lamps used by the writer is shown in Figs. 41 and 42.

Chromatic Aberration.

The reader will have noticed in reading those portions dealing with the methods of photographically reproducing the transmitted picture, that the light which passes through the receiver for the purpose of recording the signals is concentrated as a small point upon the photographic film by means of a lens. As most photographers know, light really consists of a number of coloured rays of different wave length, which, when combined, produce what is commonly known as white light. The colours which produce white light are red, orange, yellow, green, blue, indigo, and violet, and of these the red rays possess the longest wave length and the violet the shortest.

When a pencil of white light is passed through a single converging lens, the rays which compose

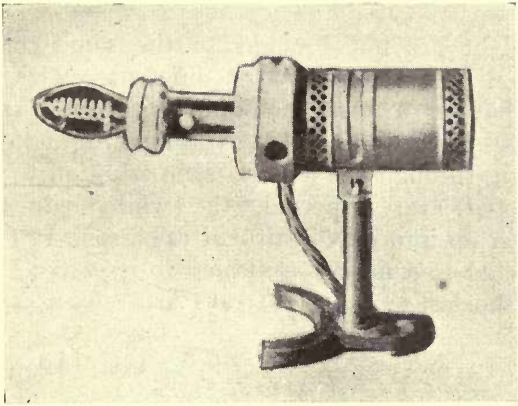


Fig. 41

PHOTOGRAPH OF NERNST LAMP

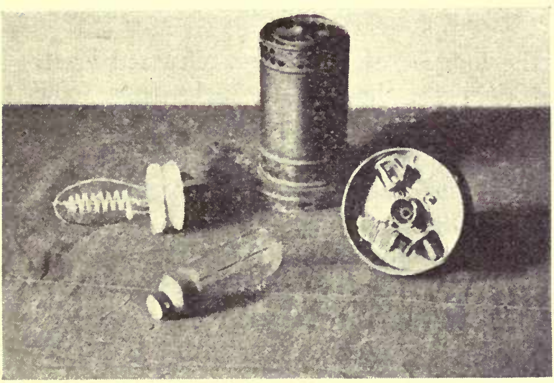


Fig. 42

COMPONENT PARTS OF NERNST LAMP

the light are not brought to the same common focus but are refracted at different angles, each ray having a focal point of its own. This is clearly shown in Fig. 43. The light from P, after passing through the lens L, is, in addition to being refracted also dispersed, the white light being broken up into its constituent rays, each ray being refracted to a degree according to its wave length. The shortest, most rapid rays are refracted most,

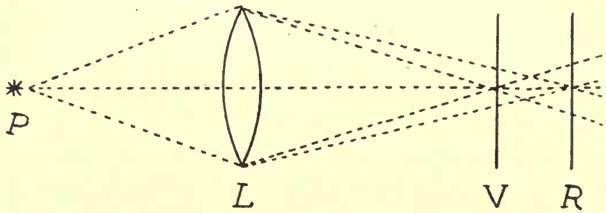


Fig. 43

and the longest, slowest rays refracted least. The violet rays are therefore brought to a focus near the lens at a point V, and the red rays brought to a focus at a point R; the remaining rays being brought to a focus at points between the two focal points V and R. If we place a white card at the point V, we shall obtain a violet image with a red border, and similarly, by placing the card at R, we shall obtain a red image with a violet border. This defect of a lens is known as "chromatic aberration."

This aberration can be corrected by combining two or more lenses of different material to form a compound lens, to so control the direction of the dispersed rays that they may recombine and so form a focus of the same colour as the original light. A lens so corrected is called "achromatic." For photographic purposes it is necessary that the lens used should be corrected not only for the orange, yellow, and green rays by which the image is focused, but also for the blue, indigo, and violet rays by which the image is produced, it being necessary that all these rays should combine at the same common focus. The orange, yellow, and green rays are termed visual rays, and the blue, indigo, and violet, chemical or actinic rays.[1] A lens that is required solely for visual purposes need not be corrected for the chemical rays.

It is essential, therefore, that the lens which is used to focus the light upon the revolving film should be achromatic, for if a non-achromatic lens is employed, it is obvious that the spot of light focused upon the film will consist of one or more of the visual rays instead of the more powerful actinic rays, with the result that the received image will be badly blurred, for, as was observed from Fig. 43, the violet rays coming to a focus nearer the lens would diverge and overlap the visual rays which have been brought to a focus on the film, thus causing a much larger impression to be recorded than desired. On the other hand if the light is

[1] The orange, yellow, and green rays give the brightest illumination and the feeblest chemical action, and the blue, indigo, and violet rays the feeblest illumination but the most powerful chemical action ; therefore with a single lens when an image is in focus to the eye the visual rays are in focus but the chemical rays are not.

passed through a smaller aperture on to the film, as in the case of Prof. Korn's telautograph (see Chapter IV), the visual light will be in focus upon the aperture, but very few, if any, of the chemical rays will find their way through on to the film. As a result the negative will be badly under-exposed, and in order to enable the weaker chemical rays to produce even a slight developable image upon the film, it will be necessary to work at a much slower speed for both transmitting and receiving.

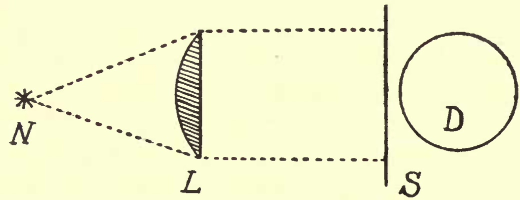


Fig. 44

With the actinic rays correctly focused by means of an achromatic lens, this reduction in working speed is not necessary.

Avoidance of Chromatic Aberration.

A method used by the writer which has given every satisfaction is shown in Fig. 44, and is as follows: It is well known that when parallel rays of light fall upon a convex lens as at L (Fig. 45) the rays are refracted, and they converge on the other side of the lens to a point F, which is known as the principal focus of the lens. Conversely, if a source of light is placed at the principal focus of a lens, the light is not converged but is transmitted as a parallel beam the same diameter as the lens. In the arrangement to be described the source of light N is placed at the principal focus of the condensing lens L, which is a plano-convex lens, the convex side being turned towards the light and the plane side towards the screen S. This screen which is placed almost in contact with the drum D, contains an aperture of a diameter equal to the lateral movement of the drum during one revolution. The negatives obtained by this method are rather hard, the bands of marking which compose the picture being perfectly opaque and sharply defined, whereas by using a lens to concentrate the light upon the film the results are more or less diffused, which although rendering the resulting picture more truly photographic in appearance is a disadvantage from the photo-engravers' point of view. No advantage has been obtained by using monochromatic in the place of white light.

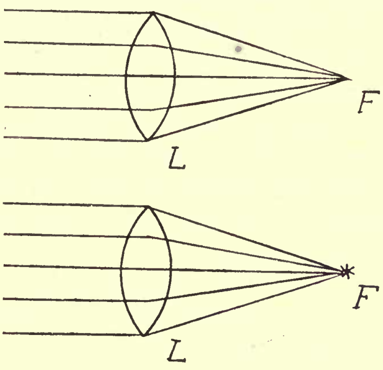


FIG. 45

CHEMICAL INERTIA.

Another point of considerable interest, and which must be taken into account, is the chemical inertia of the photographic film. With every make of film it is possible to give so short an exposure that although light does fall upon the film it is not sufficient to overcome the chemical inertia, and it does no work at all. In other words, we can say that for every make of film there is a minimum amount of light action, and that anything below this is of no use. The exposure that enables the smallest amount of light action to take place is termed the limit of the smallest useful exposure.

There is also a maximum exposure in which the light affects practically all the silver in the film, and any increased light action has no increased effect. This is termed the limit of the greatest useful exposure.

In photo-telegraphy the length of exposure is determined by the time taken by the transmitting stylus to trace over a conducting strip on the metal print, and this time varies with the density of the image and the speed of transmission.

In ordinary photography the film or plate is chosen with regard to the subject and the existing light conditions, and the amount of light admitted to the film and the length of exposure are regulated accordingly. No such latitude is, however, possible in photo-telegraphy. The various factors such as the light value, the amount of light admitted to the film, and the length of exposure will be practically fixed quantities, and the film that will give the most satisfactory results under these fixed conditions can only be found by the rough and ready method of "trial and error," and the film found to be most suitable in one case will perhaps give very unsatisfactory results in another.

The most suitable film to use for purposes of photo-telegraphy is one having a fairly slow speed in which the range of exposure required comes well within the limits of the film. There is no advantage in using a film having a speed of, say, H. & D. 300 if good results can be obtained from one with a speed of, say, H. & D. 200. The use of the high-speeded films tends towards over-exposure, besides which the difficulties of development are greatly increased, there being more latitude in both exposure and development with the slower speeded films and consequently a better chance of obtaining a good negative.

Light Sensitiveness of Films.

The light sensitiveness or the speed of plates and films is generally indicated by a number, termed the " Actinograph " number or speed number, and the system of standardization adopted by the majority of makers in this country is that originated by Messrs Hurter & Driffield, abbreviated H. & D. In their system the speed of the film and the exposure varies in geometrical proportion, a film marked H. & D. 50 requiring double the exposure of one marked H. & D. 100.

The highest number denotes the highest speed, the exposure varying inversely with the speed.

CHAPTER VIII

TELEVISION

Television is that branch of photo-telegraphy whereby the actual presentment of a person or subject placed at the transmitter can be produced at a distance instantaneously and automatically, and although television is theoretically and experimentally possible, it is, at present, from a commercial point of view, impracticable.

The early workers imagined that the discovery of selenium and its remarkable properties would enable the problem of television to be readily solved, but from the beginning two serious difficulties presented themselves ; obtaining complete synchronism between the instruments at the transmitting and the receiving station, and the slowness of the selenium in responding to the very rapid changes in the illumination that were necessary, the whole process of building up the secondary picture being required to take place in less than one-tenth of a second, which is the time that a visual impression is retained upon the retina of the eye, television being based upon that defect of the eye commonly known as the persistence of vision.

Simple Television Apparatus.

In order to understand more readily how television is possible let us study Fig. 46. The screen A, at the transmitting end, is divided into a number of squares, each square being composed of a small selenium cell. A similar screen C is employed at the receiving end, but in place of the selenium cells each square is fitted with a small electric lamp. Two wires are brought away from each selenium cell, one wire from each cell being connected separately to one terminal of each lamp in such a manner that the cell in the first square

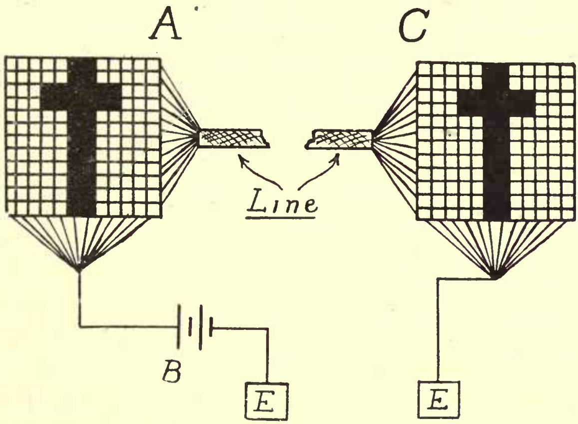


FIG. 46

at the transmitter is connected to the lamp in the first square at the receiver, and so on. The remaining wires from the cells are brought to a common junction and connected to the positive pole of the battery B, the negative pole being connected to earth. The remaining wires from the lamps at the receiver are joined together and also connected to earth. The voltage of the battery and the resistance of the selenium cells are so chosen that when the cells are unexposed to the action of light the current flowing through the various circuits is just not sufficient to light the lamps. If now the shadow of an image is projected upon the mosaic of selenium cells, as shown in the figure, those cells which are illuminated will have their resistance lowered to an extent that sufficient current will flow through the line to light the lamps in the corresponding squares, and those cells which remain unexposed, and which form the simple image at the transmitter, will have their corresponding lamps in darkness to form a replica of the image at the receiver.

Although television is possible with apparatus similar to that just described it must not be regarded as a practical method, as the expense would be enormous, besides which the difficulties of manufacturing a large number of similar selenium cells would prove almost insurmountable. From some calculations made by Shelford Bidwell, one of the early workers, to receive a picture 2 ins. by 2 ins., with a grain as fine as an ordinary newspaper illustration, would necessitate the employment of at least 40,000 selenium cells, and to transmit such a picture over a distance of 100 miles would cost approximately one and a quarter million pounds.

The above method of television, although capable of producing an instantaneous picture, does not depend for its action upon the persistence of vision. Messrs. Ayrton and Perry, in their early experiments in television, endeavoured to make a few moving selenium cells do the work of a large number of stationary cells, and this, while reducing the expense and the complexity of the apparatus, renders it necessary to employ high speed instruments of a very accurate character, as there must be absolute synchronism between the transmitter and the receiver. Briefly their arrangements were as follows.

AYRTON AND PERRY'S APPARATUS.

At the transmitting station an image in monotone of the subject to be telegraphed is thrown upon a transparent screen, and at the back of this screen a selenium cell is so arranged as to pass with a to-and-fro movement over the entire surface of the image. According to the amount of light which fell upon the selenium cell, depending upon the varying densities of the image, more or less current flowed through the line wires to the receiver. The receiving instrument consisted of a great number of small magnetized needles (working similar to an ordinary telegraph instrument) controlled by means of the varying currents flowing through the line wires. As the selenium cell traced its path over the image on the transmitting screen, the magnetized needle occupying the same relative position on the receiving screen was connected to the line wires, each needle by its movement uncovering a small aperture, allowing light to pass through and illuminate the screen which consisted of a sheet of frosted glass.

The main idea of this system really consists of the employment of two synchronized distributors which connects together small portions of the transmitter and receiver in regular succession, it being necessary, in order to obtain a visual impression, that the entire number of portions into which the transmitter is divided is connected to a similar number of portions on the receiver, and that the complete cycle of operations shall take place in less time than one-tenth of a second. When tried, it was found that the mechanical arrangements for driving and synchronizing the distributors could not be made sufficiently accurate, it being necessary, in order to produce even a passable image, to arrange for about 100,000 contacts a second.

Kerr's Receiver.

A method of receiving proposed by Prof. Kerr was to have the receiver made up of a mosaic of very small electro-magnets, the ends of the cores to terminate in a square of silvered soft iron. The surface formed by this mosaic of silvered iron cores was to be illuminated by plane polarized light, by reflection from glass, the rays from each magnet face being received by an analyzing prism. The plane of polarization of the various beams of light can be rotated by increasing the magnetic effect of each magnet, and as the intensity of the light rays passing through the analyzing prisms depends upon the angle of rotation, which again depends upon the amount of current flowing through each magnetic coil, it is evident that the intensity of the rays of light passing through the analyzing prisms will vary according to the amount of light falling upon the selenium cell at any instant as it passes to and fro over the illuminated image at the transmitter.

RIGNOUX AND FOURNIER'S METHOD.

Another method of receiving, also making use of polarized light, has been devised by Rignoux and Fournier, and although originally intended for use with their proposed television apparatus, has also been successfully employed over short distances

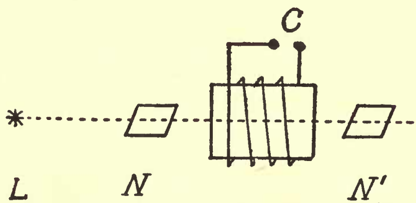


FIG. 47

for ordinary photo-telegraphy. The idea is shown in Fig. 47. A ray of monochromatic light from a convenient source L passes through a Nicol prism N, termed a polarizing prism, then through a tube containing carbon bisulphide, and afterwards through a second Nicol prism N′, termed an analyzing prism; we shall find that if the two prisms are set at the polarizing angle no light will reach and pass through the prism N′. Upon the tube being subjected to a field produced by a current passing through the coil C, the refractive index of the liquid will be changed, enabling light from L to pass through the prism N′.

Although it is possible to construct apparatus for television on lines similar to what has already been described, as previously pointed out, any such system would be commercially impracticable, owing to the great expense, intricacy, and the mechanical difficulties involved in arranging for such a large number of rapid synchronized movements.

It was for these reasons, apart from any apparent lack of possible application, that the subject of television dropped somewhat into the background, it being soon realized that the difficulties were much less when attempting to transmit a photograph that had already been taken and which could be retained for purposes of transmission as long as desired, as in ordinary photo-telegraphy, than in television, where the received image has to be formed practically instantaneously.

Campbell Swinton's System of Transmission.

More recently, however, a method of television on more practical lines has been suggested by Mr. A. A. Campbell Swinton, and was given in detail in his presidential address to the Röntgen Ray Society for the session 1914-1915. The principle of the system is based upon the extreme susceptibility of the cathode ray discharge of an X-ray tube to magnetic influence. When placed in a magnetic field produced by a rapidly alternating current, the cathode rays can be made to oscillate with extreme rapidity, as they are practically weightless and possess little or no inertia. The arrangement can be followed out by a study of Fig. 48.

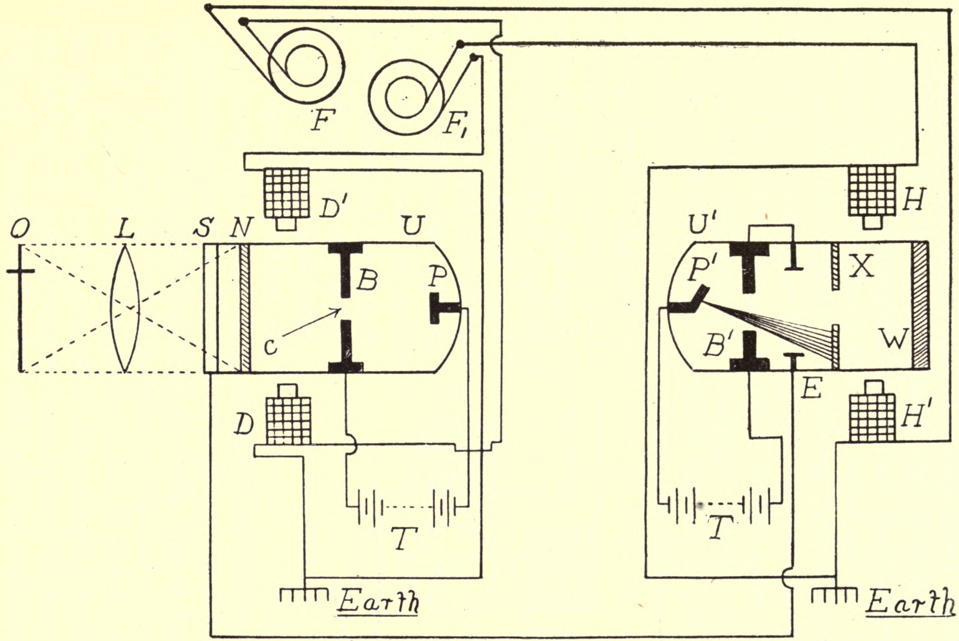


FIG. 48

The transmitter consists of an X-ray tube U connected by the terminals T to suitable electrical apparatus, P being the cathode and B the anode; the anode being provided with a small circular aperture *c* in the centre. At the end of the tube opposite the cathode is placed two screens, the screen N, composed of a large number of small cubes of the metal rubidium, which is photo-electrically active under the action of light, and the screen S of fine metallic gauze.

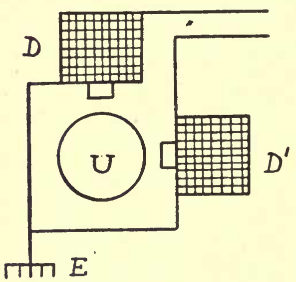


FIG. 48*a*

The place between the two screens S and N is gas tight, and filled with sodium vapour, which has been found to conduct negative electricity more readily when illuminated than in the dark. The image to be transmitted is thrown by the lens L upon the screen N, and in passing through the gauze screen S the image is broken up into small portions, a portion being thrown upon each of the small metal cubes of which the screen N is composed (the cubes are insulated from each other), each cube being illuminated to an extent depending upon the varying density of the image O. Two magnets, D and D′, are placed at right angles to each other as shown in Fig. 48*a* (they are shown opposite in Fig. 48, to avoid confusion). One end of the winding of each coil is connected to earth, the other ends being connected to two alternators, one end from the coil D being connected to one terminal of the alternator F, and the end from D′ to one terminal of the alternator F′.

The receiver consists of an X-ray tube U′, with two magnets similar to those used at the transmitter, one end of the winding of the coil H being connected by the line wire to the remaining terminal on F, and one end of the winding of H′ being connected by the line wire to the remaining terminal on F′. The two other connections on H and H′ are connected to earth.

Inside the receiving X-ray tube U′, besides the cathode P′ and the anode B′, there is a small metal plate E, and a diaphragm X, which contains a very small aperture, the plate E being placed in such a position that the cathode rays just pass over its surface. The aperture in the circular anode B′ is placed in such a position that the rays which are thrown off from the inclined cathode P′ do not pass through the aperture in the diaphragm X, except under certain conditions when working, the fluorescent screen W normally remaining in darkness. The plate E is connected by a line wire to the metal gauze screen S on the transmitter.

MODE OF OPERATION.

The action is as follows: The alternator F′, energizing D′ and H′, has a very low frequency, while F, energizing D and H, has a very high frequency. The cathode ray at the transmitter can, when the magnets D and D′ are energized by alternating current, be made to search out the whole surface of the screen so rapidly that the illumination appears instantaneous. Let us suppose that the screen N at the transmitter is being illuminated by the image of the object O. It is evident that each of the metal cubes of which the screen is composed will be illuminated to an extent depending upon the density of that portion of the image falling upon it.

As the cathode rays pass over the surface of the screen N, each cube is given a negative charge. Those cubes that have received a dark portion of the image and are therefore unexposed will undergo no further action, but with those cubes that are illuminated the negative charge will pass away through the ionized sodium vapour to the gauze screen S, and along the line wire to the plate E at the receiver. This plate thus becomes negatively charged and repels the cathode rays, with the result that they can pass through the aperture in the diaphragm X, and record a spot of light upon the fluorescent screen W. As the magnets H and H′ are energized at exactly the same time as the magnets D and D′, the receiving cathode beam takes up exactly the same position on the screen W as the transmitting beam on the screen N. As the entire cycle of operations takes place in less than one-tenth of a second, a seemingly stationary image of the object O will be seen upon the screen W.

CHAPTER IX

THE WIRELESS TRANSMISSION OF PHOTOGRAPHS

The latest phase of the science of photo-telegraphy, and one which undoubtedly possesses great possibilities, is its application to wireless transmission. Rapid and wonderful as the recent developments in wireless science have been, yet, at first sight, the transmission of a picture or photograph by means of wireless apparatus seems a difficult, not to say an almost impossible problem. Recent experiments, however, have proved that a solution to the problem is not only probable but possible, the difficulties to be overcome being no greater than those encountered by other pioneer workers in the various fields of scientific research.

Radio-Photographic System.

For several years the writer has been engaged in experimenting in radio-photography, and has evolved a system from which very good results—in half-tone—can be obtained over a distance of several miles. In a small volume on radio-photography,[1] published by the writer, a description of his early apparatus is given, and although some passable results were obtained the working of the set was far from satisfactory, so after collecting some useful information and data the work was

[1] *The Wireless Transmission of Photographs* (The Wireless Press, Ltd.).

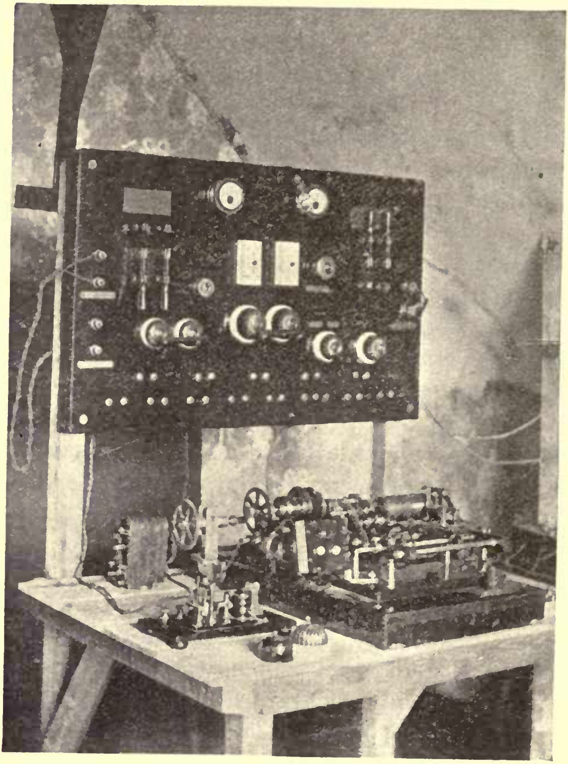


Fig. 49

PHOTOGRAPH OF AUTHOR'S COMPLETE TRANSMITTING SET continued on different lines. The apparatus at present used although fairly reliable is too complicated and it will be necessary to simplify it considerably before it is in any way suitable for commercial work.

SYNCHRONIZING THE TWO STATIONS.

This is one of the most difficult problems that

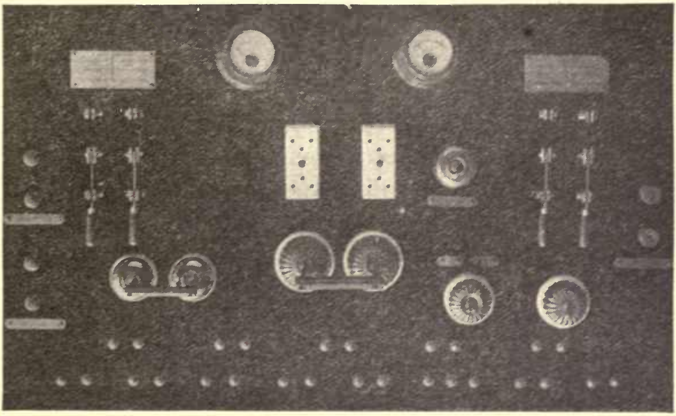


FIG. 49*a*

PHOTOGRAPH OF SWITCHBOARD FOR USE WITH THE AUTHOR'S RADIO-PHOTOGRAPHIC APPARATUS

require solving in connection with radio-photography as it must be very nearly perfect in order to obtain intelligible results, the limit of error requiring to be less than 1 in 500 in order to obtain results suitable for publication. The difficulty of synchronism has been practically overcome in the various systems of wire photography, and some modification of these methods will perhaps solve the problem, but it must be remembered that synchronism is far easier to obtain where the two stations are connected by a length of line than where the two stations are running independently.

Of the various methods of receiving that have been devised for photo-telegraphy, only two are at present applicable to wireless work, the two methods being (1) by means of the electrolytic process, and (2) by means of an ordinary photographic process.

Although both these methods have been used in ordinary wire photography with great success they have certain disadvantages when applied to wireless work. The electrolytic method requires a much heavier working current than any photographic process, the former requiring at least ·5 of an ampere to produce electrolysis, whereas a sensitive photographic receiver can be made to work with as small a current as $\frac{1}{5000}$ of an ampere.

Isochronism.

This may be explained as follows: Two clocks would isochronize if their hands travelled at precisely the same rate round the dials, but would not synchronize unless they both registered the same time as well. Up to the present this still remains a difficulty to be overcome, the present methods being far from satisfactory. With the electrolytic method of receiving, isochronism is fairly easy to obtain as the received image is visible, and any minor adjustments necessary can be made while working, while with a photographic method of reception, once the final adjustments have been made the operator cannot know of the fault until the picture has been received and developed. The method of isochronism employed must, however, be nearly perfect in its action as it is easy to see that with only a very slight difference in the speed of either machine this error will, when multiplied by 40 or 50 revolutions, completely destroy the received picture for practical purposes.

It is not desirable, neither is it possible to give here a detailed description of the various methods devised for the wireless transmission of photographs, but those that are interested in this branch of photo-telegraphic work are advised to read the volume previously mentioned, as they will then be able to appreciate the difficulties to be overcome and the advantages to be gained from the introduction of a reliable wireless system.

Any system of wireless photography to be commercially successful must be simple, rapid, and as far as possible automatic in its action, there being necessarily a large number of instruments all requiring careful adjustment and depending upon each other for successful working.

CHAPTER X.

DESIGN FOR EXPERIMENTAL MACHINE FOR PHOTO-TELEGRAPHY

THE machine to be described in the following chapter was designed by the author purely for experimental work, and has been used by him throughout the whole of his experiments. The present design, however, differs slightly from the original, but the difference is such as only to render the machine easier to construct, the compactness and efficiency remaining unaltered.

As regards the actual construction, this should present no serious difficulty to those who can turn out fairly accurate work, and as accuracy is a *sine qua non* a little extra time in setting out and in machining will save endless time, trouble, and spoilt work, to say nothing of the more accurate results obtained in working. Although the building of one machine only is considered, it is, of course, obvious that two machines will have to be provided, one at each station, before any serious work can be undertaken. A photograph of the original machine is given in Fig. 33 (Chapter IV).

BASEPLATE.

A pattern will be required for the baseplate, which is an iron casting, the finished dimensions being given in Fig. 50. The central rib is not absolutely necessary, but it will act as a preventive,

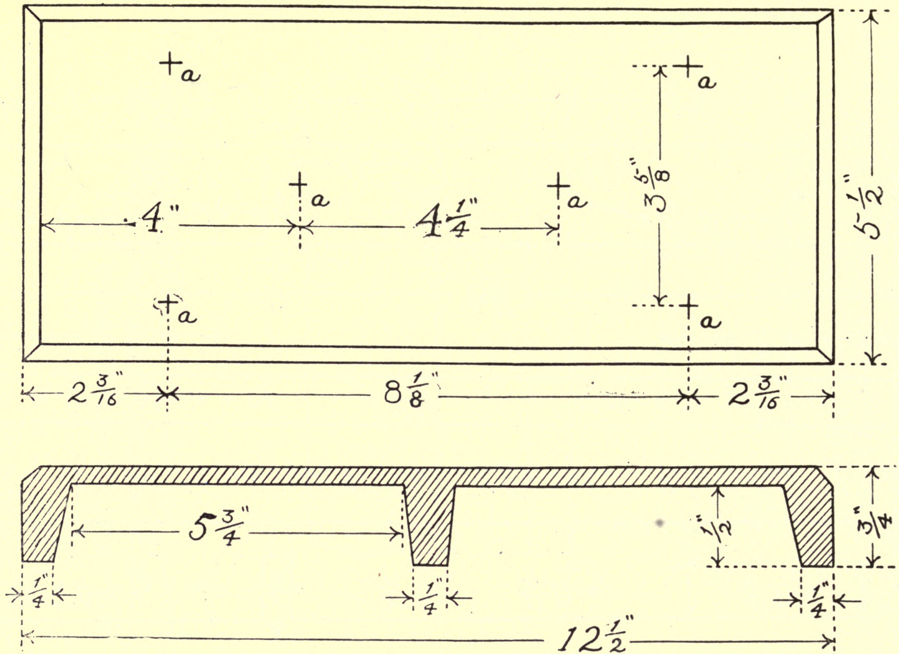


FIG. 50

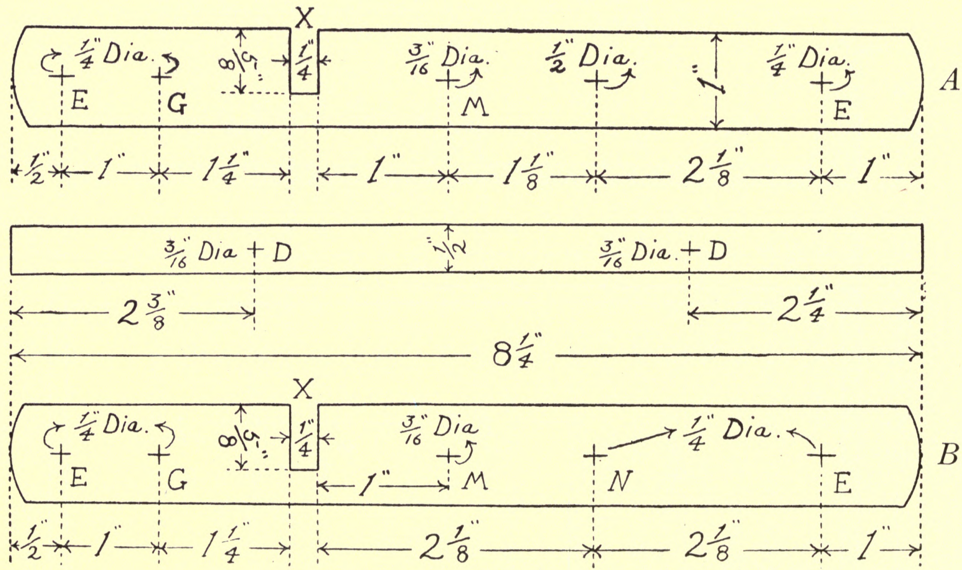


FIG. 51

should there be any tendency to twist while the casting is cooling. The surface is preferably planed, but if this is not convenient filing must be resorted to. The holes *a* are all drilled a full $\frac{1}{4}$ in. in diameter.

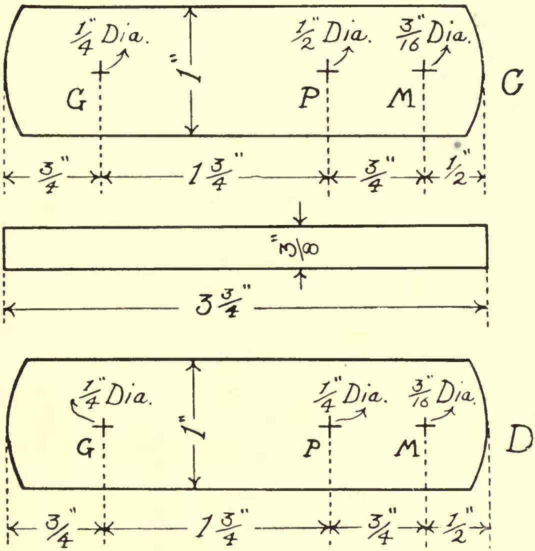


Fig. 52

The four outside holes are to take the standards (Fig. 53), and the two central holes are for holding-down bolts. The framework is made from rectangular steel bar, which can be bought polished of the required section, the two side bars A and B (Fig. 51) being $\frac{1}{2}$ in. by 1 in., and the two upright pieces C and D (Fig. 52) being $\frac{3}{8}$ in. by 1 in. They should be marked out and the holes bored from both sides in order to get them as accurate as possible, perfect alignment being necessary. The two ½ in. diameter holes in the plates A (Fig. 51) and C (Fig. 52) should

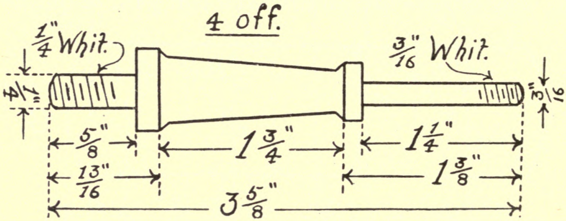


Fig. 53

be turned out in the lathe. They are to take the bushes given in detail in Fig. 56. Care must be taken in drilling the four $\frac{3}{16}$ in. holes in the side bars (Fig. 51), and they should be a little full to allow the shanks of the standards to enter easily.

Tie Rods and Standards.

The standards (Fig. 53) and the tie-rods (Fig. 54)

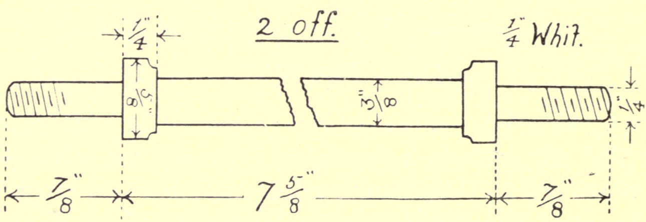


Fig. 54

are turned from ⅝ in. mild steel rod. The tie-rods can be built up if desired, the ends being turned separate and sweated on to a length of ⅜ in. steel rod, as shown in Fig. 55, rather a lot of work being entailed by turning them from $\frac{5}{8}$ in. rod. The two bushes A and B (Fig. 56) are turned from $\frac{3}{4}$ in. brass rod, and should fit tightly in the holes in their respective plates, the bush A fitting into the plate A (Fig. 51), and the bush B into the plate C (Fig. 52). The bushes A and B and the nuts D are threaded and tapped with a fine brass thread

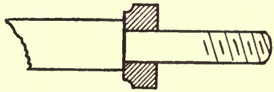


FIG. 55

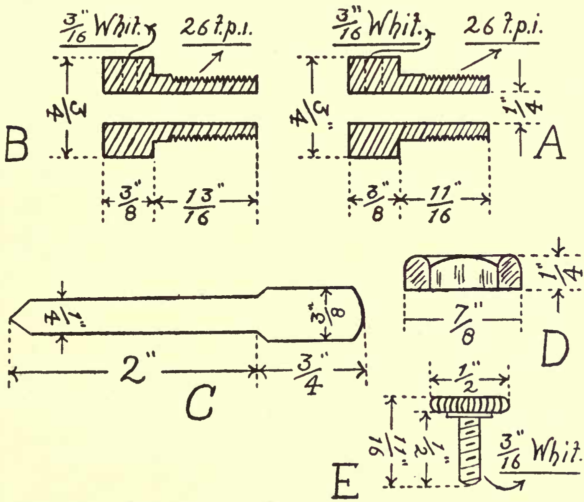


FIG. 56

(26 t.p.i.) and the holes in the bushes to take the set-screws E (Fig. 56) are tapped $\frac{3}{16}$ in. Whitworth. The steel spindles C (Fig. 56) are turned from $\frac{3}{8}$ in.

steel rod, and the ends are turned to a taper of 60°. If desired these can be hardened, but it is not really necessary, as there is very little wear and any slack is easily taken up; the spindles must be a good sliding fit in the bushes. The holes N

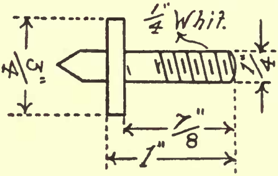


FIG. 57

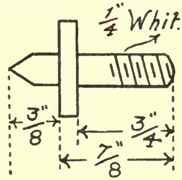


FIG. 57a

and P in the plates B and D (Figs. 51 and 52) that come opposite the bushes are to take the fixed bearings given in Figs. 57 and 57*a*. The taper of these is also 60°, and both are similar in size except the shanks, one being $\frac{1}{8}$ in. longer than the other.

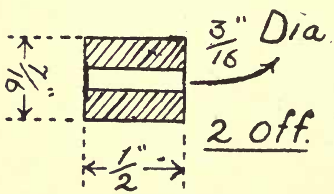


FIG. 58

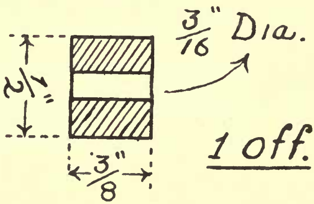


FIG. 59

To complete the framework there will be required two steel distance pieces $\frac{7}{16}$ in. in diameter and $\frac{1}{2}$ in. long, a $\frac{3}{16}$ in. hole being drilled through the centre, and one distance piece $\frac{1}{2}$ in. in diameter and $\frac{3}{8}$ in. long (Figs. 58 and 59). The two side stays (Fig 60) are of $\frac{1}{2}$ in. by $\frac{1}{8}$ in. steel, the holes M being drilled $\frac{3}{16}$ in. in diameter. The bracket (Fig. 61) is cut to the shape shown from a piece of mild steel plate $\frac{1}{8}$ in. thick, the slots being drilled and filed out.

Assembling the Frame.

The framework can now be assembled. Two hexagon-headed steel bolts will be needed, one $\frac{1}{4}$ in. by $1\frac{3}{4}$ in., and one $\frac{1}{4}$ in. by $1\frac{1}{4}$ in.; also four $\frac{3}{16}$ in. hexagon bolts, two $1\frac{1}{4}$ in. long, one

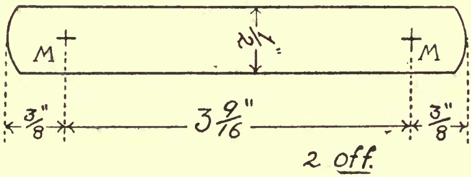


Fig. 60

$1\frac{3}{8}$ in., and one $\frac{7}{8}$ in. long; also some $\frac{3}{16}$ in. and $\frac{1}{4}$ in. steel hexagon nuts (Whitworth thread), with chamfered washers to match. For the sake of appearance model nuts should be used, the standard sizes looking rather clumsy.

The bushes and fixed bearings should be bolted into their respective holes, and the tie-rods (Fig. 54) inserted into the holes E in the side plates (Fig. 51). The four standards (Fig. 53) are fastened into the $\frac{3}{16}$ in. vertical holes D in the plates A and B (Fig. 51), and the main frame can then be fixed on the base plate. If the holes drilled in the base do not exactly correspond with the standards, they can be drawn slightly so that the shanks fit in easily. The plate D (Fig. 52) is bolted on to the plate B (Fig. 51) by means of a $\frac{1}{4}$ in. by $1\frac{1}{4}$ in. bolt passed through the holes G, and the plate C is bolted in a similar manner to the plate A with a $\frac{1}{4}$ in. by $1\frac{3}{8}$ in. bolt, only in this case the bolt is first passed through the slot D in the plate (Fig. 61).

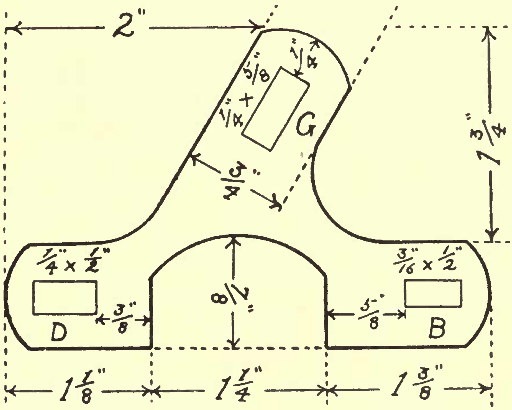


FIG. 61

The side stays are next put into position, the $\frac{3}{16}$ in. by $1\frac{1}{4}$ in. bolts being used to bolt them to the plates C and D (Fig. 52), the two distance pieces (Fig. 58) being placed between the stays and the plates to keep them parallel with the side bars A and B (Fig. 51). The $\frac{7}{8}$ in. bolts hold the bottom of one stay to the bar B, and the $1\frac{3}{8}$ in. bolt is passed through the slot B in the plate (Fig. 61) through the distance piece (Fig. 59) and through the side bar A and stay. The holes for these stays are marked M, and when the nuts are tightened up the plates C and D (Fig. 52) should be perfectly square with the plates A and B (Fig. 51), and the fixed and movable points in perfect alignment. It will be seen from Fig 33 (Chapter IV) that there

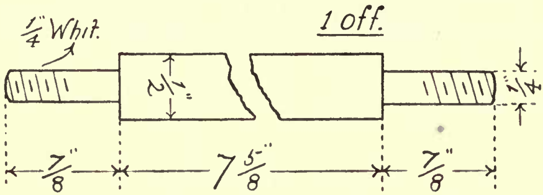


FIG. 62

are two extra tie-rods at the top and bottom of the plates C and D (Fig. 52), but in the present design these have been dispensed with, as they have been found unnecessary.

The slide bar (Fig. 62) is turned from $\frac{5}{8}$ in. mild

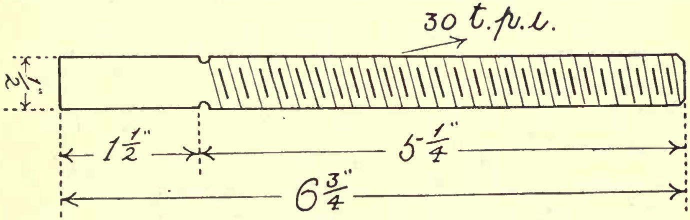


FIG. 63

steel rod to the dimensions given, and should drop tightly into the slots X in the side bars (Fig. 51), the nuts holding it in position. The slots X will be found a great advantage, as the rod can be taken out for the removal of the table without taking the whole machine to pieces, as was necessary in the original, as the slide rod passed through holes in the side bars. The lead screw (Fig. 63) is turned from a piece of mild steel rod to the dimensions given, the ends being countersunk as shown in Fig. 63*a*, in order that it can run easily between the tapered bearings in the side bars A and B (Fig. 51). The thread cut is 30 to the inch.

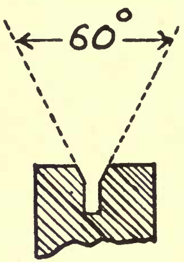


FIG. 63*a*

THE CYLINDER.

The cylinder (Fig. 64) is next taken in hand. The shaft S is turned from mild steel rod to the dimensions given, the ends being countersunk in a similar manner to the lead screw. The circular plates D are turned from brass plate $\frac{1}{4}$ in. thick, the central hole being a tight fit for the reduced portion of the shaft S. The two plates are held firmly against the shoulders of the shaft by means of tie-rods which pass through the holes C. These tie-rods B consist of two $3\frac{3}{4}$ in. lengths of $\frac{1}{8}$ in. diameter hard drawn brass rod, threaded for about $\frac{3}{8}$ in. each end and fitted with hexagon nuts. The shell of the cylinder consists of a 4 in. length of $1\frac{3}{4}$ in. (outside diameter) solid drawn brass tube, and should be about No. 16 gauge. The two plates D are turned a tight fit for the inside of the tube, and are sweated in position, the tube overhanging the plates about $\frac{1}{4}$ in. each end.

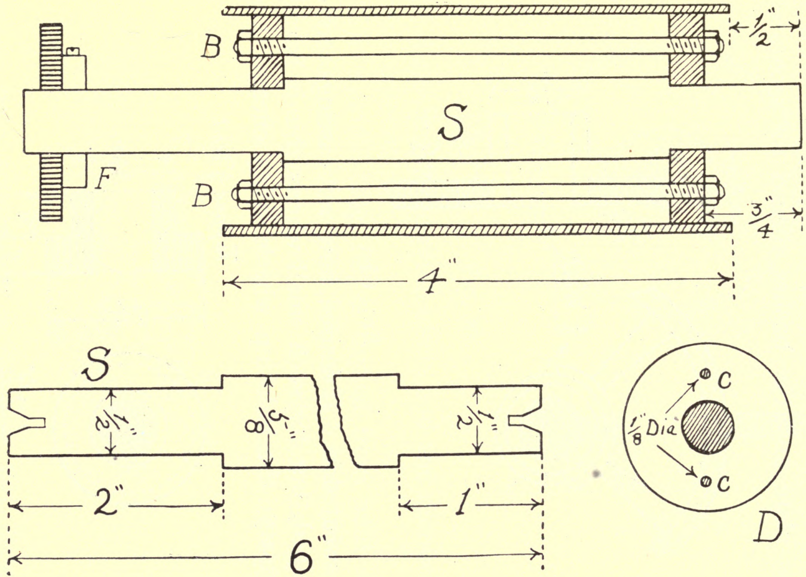


FIG. 64

GEARING.

Details of the gearing are given in Figs. 65, 66, and 67, and, as shown, the blanks are cut from brass plate and the bushes turned up separately

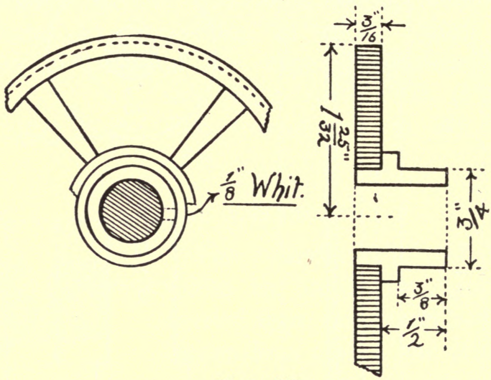


FIG. 65

and sweated in. If desired, however, castings can be obtained, but for such small wheels this is hardly necessary, the built up wheels being cheaper and

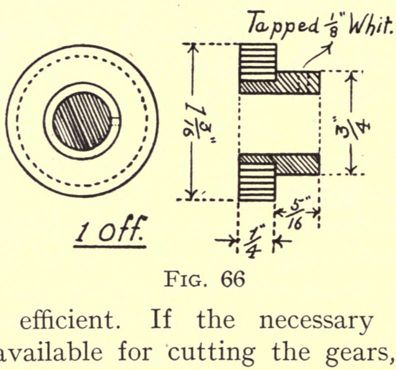


FIG. 66

quite as efficient. If the necessary appliances are not available for cutting the gears, there are several firms who make a speciality of this kind of work, it being only necessary to send them the blanks turned to the right diameter, and stating

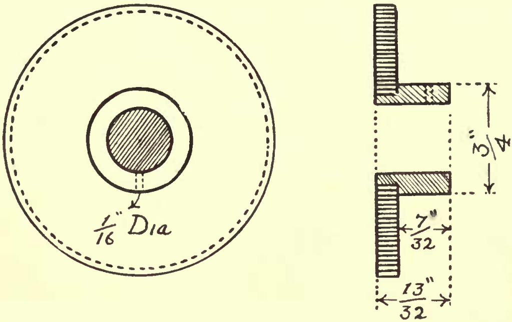


FIG. 67

the diameter of the pitch circle and the number of teeth required.

The spindle (Fig. 68) is turned from mild steel rod, and the wheel (Fig. 67), which has 125 teeth should run freely but not loosely on the $\frac{7}{16}$ in. portion, a small washer $\frac{5}{8}$ in. in diameter, with a $\frac{3}{16}$ in.

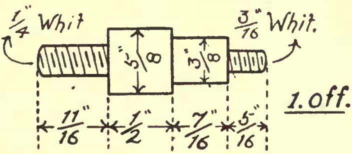


FIG. 68

central hole, secured by a hexagon nut, keeping the wheel in position. The wheel (Fig. 66), which has 60 teeth, should be fitted on the cylinder shaft S (Fig. 64), and the wheel (Fig. 65) on the lead screw

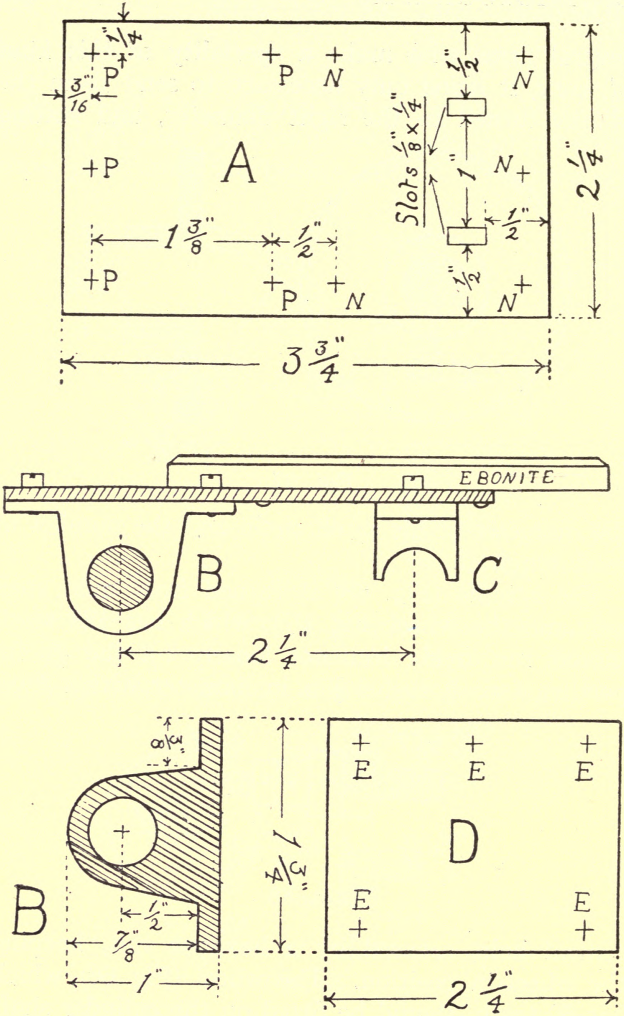

A
P
N
Slots 1/8" x 1/4"
3/16"
1/4"
1/2"
1"
1 3/8"
2 1/4"
3 3/4"
EBONITE
B
C
2 1/4"
B
D
E
3/8"
1 3/4"
1/2"
7/8"
1"
2 1/4"

Fig. 69

(Fig. 63). The lead screw and cylinder are then placed in their respective positions between the coned bearings, and the final adjustments of the gears made. The wheels (Figs. 65 and 66) are secured in position with $\frac{1}{8}$ in. set-screws, and the middle gear is adjusted by moving the spindle in the slot G in the plate (Fig. 61), and also by shifting the plate until the right position is obtained. The wheel (Fig. 65) has 180 teeth.

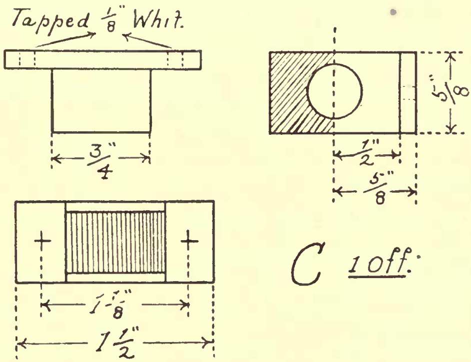
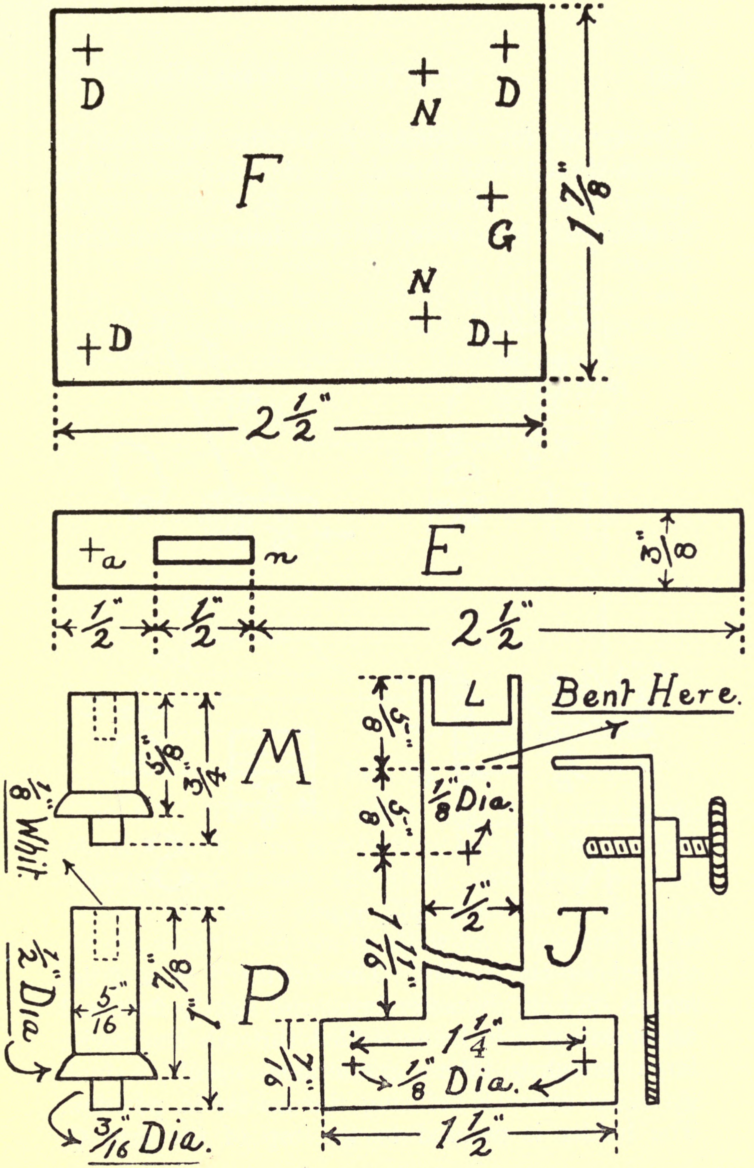


FIG. 70

The table is given in detail in Figs. 69 and 70, and consists of the plate A, to which is attached the slide B and half-nut C. The plate A is of $\frac{1}{8}$ in. steel, holes $\frac{1}{8}$ in. in diameter being drilled in the positions marked P and N. In D, which is a plan of the slide B, holes should be drilled at E to correspond with the holes P in the plate A, and tapped $\frac{1}{8}$ in. Whitworth. The slide B is a brass casting, and the hole bored through the centre must be an accurate sliding fit for the slide-rod (Fig. 62). This slide is fastened to the plate A with $\frac{1}{8}$ in. by $\frac{1}{4}$ in. steel screws. The half-nut (Fig. 70) can be either a casting or cut from a piece of brass bar, and the central hole is bored and threaded to fit the lead screw (Fig. 63). After being threaded the shaded portion is removed, so that on the completion of its journey the table has only to be lifted up and slid along in order to bring it back to its starting point. It is evident that the slide rod and lead screw must be absolutely parellel, otherwise the table will not travel freely. The half-nut is secured to the plate A by $\frac{1}{8}$ in. by $\frac{7}{16}$ in. bolts and nuts, the slots in A allowing for adjustments.

THE STYLUS.

The stylus (Fig. 71) will be described next. The plate F is cut from sheet brass $\frac{1}{8}$ in. thick, and holes drilled in the positions marked. The holes D are $\frac{3}{32}$ in. in diameter and $\frac{3}{16}$ in. from each edge, and the hole G is central and $\frac{1}{4}$ in. from the back edge of the plate. The holes N are drilled $\frac{5}{16}$ in. from the sides and $\frac{5}{8}$ in. from the back edge of the plate; both G and N are $\frac{3}{16}$ in. in diameter. The standards M and P are turned from brass rod, the standard M being sweated in the hole G and the two standards P in the holes N. The guide J, with adjusting screw K, is screwed to the two pillars P, the slot L in the guide being the same width as the brass spring E, which is screwed to the standard M. This spring is cut from stiff springy brass to the dimensions given, and a small terminal is fastened at *a*.



F
D
N
G
1 7/8"
2 1/2"
E
a
n
3/8"
1/2"
1/2"
2 1/2"
M
5/8"
3/4"
1/8" Whit.
P
1/2" Dia
5/16"
7/8"
1"
3/16" Dia.
L
Bent Here.
5/8"
5/8"
1/8" Dia.
1/2"
1 11/16"
J
1 1/4"
1/8" Dia.
7/16"
1 1/2"

FIG. 71

The screw for securing it to the standard M passes through the slot *n*. At the plain end of the spring is fastened the bent arm Q, which is made of stiff brass $\frac{1}{4}$ in. wide, the $\frac{1}{2}$ in. bent portion being

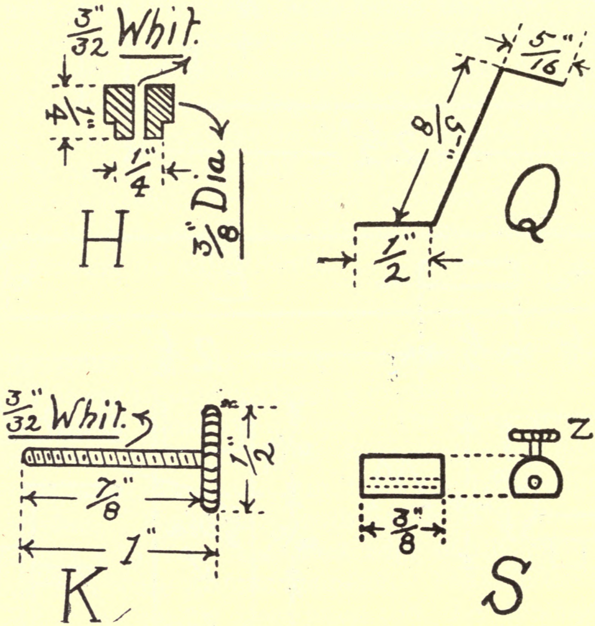


FIG. 71*a*

riveted to the spring. The holder S is a $\frac{3}{8}$ in. length of $\frac{1}{4}$ in. diameter brass rod lightly flattened as shown, a hole being drilled through lengthwise large enough to take a gramophone needle, a small $\frac{3}{32}$ in. set-screw Z securing the needle in position. The holder is secured to the top of the arm Q.

The bush H is sweated in position on the guide J, and is drilled and tapped $\frac{3}{32}$ in. Whitworth to take the adjusting screw K.

As it is necessary for the stylus to be well insulated from the rest of the machine, a piece of ebonite $\frac{1}{4}$ in. thick, $2\frac{3}{4}$ in. long, and $2\frac{1}{4}$ in. wide is screwed to the table by means of small screws passed from the underside of the table through the holes N

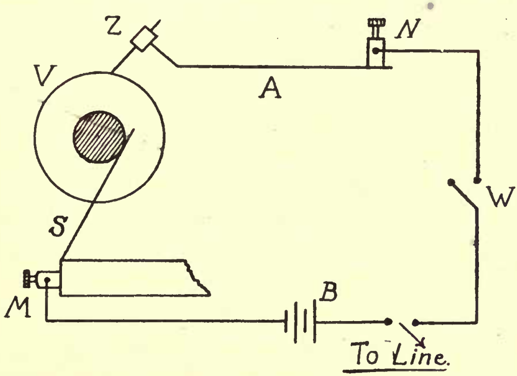


FIG. 72

(Fig. 69). The screws which hold the stylus to the ebonite block must not be long enough to pass right through and touch the table, otherwise a short circuit will take place. The ebonite block must be cut away as shown to allow for the heads of the screws, so that it can bed down properly. The position of the stylus baseplate F (Fig. 71) on the ebonite block will be about $\frac{1}{4}$ in. from the back end, and the angle which the needle presents to the cylinder should be about 60°, as this angle has been found to give very good results

CONNECTIONS.

The electrical connections are given in Fig. 72. Current flows from the battery B through the spring S, drum V, needle Z, spring A, and switch W to line, through the receiving instrument and return line back to the battery. The spring S is a thin flat steel or brass spring $\frac{3}{8}$ in. wide and 8 in. long, having a $\frac{3}{16}$ in. hole drilled $\frac{1}{2}$ in. from one end. The plate C (Fig. 73) is $\frac{3}{4}$ in. wide and 2 in. long

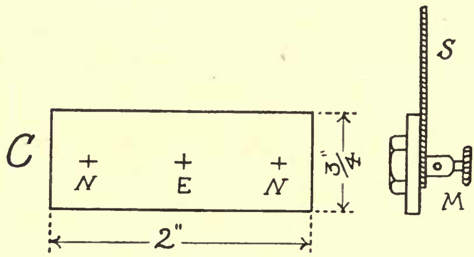


FIG. 73

by $\frac{1}{8}$ in. thick, the holes N being $\frac{1}{8}$ in. in diameter and the hole E $\frac{3}{16}$ in. in diameter, the holes being spaced equally along the centre line of the plate. A terminal with a shank about $\frac{1}{2}$ in. long is passed through the hole drilled in the spring S and through the hole E in the plate C, and secured by a spring washer and nut. The plate is screwed to the edge of the wood base on which the machine is mounted by wood screws, the holes N being provided for that purpose. The spring should pass on the inside of the cylinder shaft, between the gear F and the cylinder (Fig. 64).

BASE.

The baseboard should be of polished hard-wood, $14\frac{1}{2}$ ins. long, $6\frac{1}{2}$ ins. wide, and $1\frac{1}{4}$ in. thick, and this allows a margin around the machine base of $\frac{1}{2}$ in. at the sides and 1 in. at the ends. To finish the machine the base (Fig. 50), the side bars (Figs. 51 and 52), and the plate (Fig. 61) should be enamelled an olive green colour, the rest of the metal work being polished.

As already stated, the design of this machine, although not of the latest, is one that has been satisfactorily used for experimental work, being also fairly easy and inexpensive to construct. For methods of driving and synchronizing, reference should be made to the various systems already described, as well as the author's handbook on the *Wireless Transmission of Photographs.* The photograph (Fig. 49, Chapter IX) shows one of these machines used with the author's earliest transmitting apparatus arranged for wireless photography.

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