RAILWAY TELEGRAPHS AND ELECTRIC SIGNALS.*

BY ROBERT B. LINES.

Group ——.

The practical value of the electric telegraph is nowhere more apparent than in its application to the running and control of railways.

One of the principal claims made by Prof. Morse for the invention which he at least had the merit of first bringing into practical commercial operation, was the facility which it would offer to railways for the speedy and safe transaction of their business. While it cannot be said that the railways of either Europe or America have yet received the full benefit of this important and now, indeed, indispensable auxiliary to their management, it is certain that much has been done by the aid of the telegraph which could not have been done without it, and much of the progress made by railways within the past thirty years is due to its powerful assistance. While it has rendered possible that direct control over hundreds of miles of track, which is such a striking feature in our railway management, its detailed application has also shown it to be the most valuable, if not the only, means of maintaining safety in the midst of the immense traffic in freight and passengers which its use has aided in building up.

In America the railways have been and are still, to a great extent, too much dependent for their telegraphic facilities on contracts with telegraph companies, frequently disadvantageous to the former from the commencement, and always, as

* The attempt which has been made in this article to reduce the large drawings with which it was accompanied, by the aid of the Heliotype process, has not succeeded as well as was expected, owing to the excessive reduction necessary to bring the illustrations within the size of the page; the lettering, particularly, is imperfect. It is believed, however, that the interested reader will find no difficulty in understanding the plates by aid of the context.—Editor.

traffic increases, involving great difficulties in their practical working. In many cases, railways have been required not only to yield the right of way, but also to furnish and distribute the poles for, and otherwise to aid the erection of lines, the property in which vests in a telegraph company. The line once established, the railway is to transport men and material for its maintenance or extension and to share the expense of its operation. In return for these services it receives a partial use of the wire for its own business, the telegraph company receiving the profits from all other despatches.

This use of a railway wire for commercial business, still common in some sections, gives rise to constant disputes between the employés of the two companies, and not infrequently is productive of great delay and danger to the business of the railways. On most important lines, however, the railways of America have followed the example of those in Europe, and secured for themselves the exclusive use, if not the ownership, of one or more wires along their routes, operating them independently. Such cases alone come properly within the scope of this report, as where the control of a wire belongs to, or is even divided with a company operating it for commercial purposes, railway telegraphy can hardly be said to exist.

The telegraphic service of railways may be divided into two classes, general and special. Although this paper relates almost exclusively to the latter class, a few words with regard to the former may not be out of place.

The first class includes all messages on the ordinary business of the road, such as orders to station-masters, directions in regard to cars, to the distribution and working of forces, etc. Under this head may also be classified the regular reports to the central office and the whole system of "train despatching," or "running by telegraph," which has become so common, and been brought to such apparent perfection in the United States, but which, so far as I am able to learn, does not exist abroad.

In Europe there are generally several wires set apart for the exclusive use of railways, both for the general and the special services. In France, one wire connects the principal, another the secondary, and a third, or "omnibus" wire, all of the stations. For the ordinary service, at least on this latter wire, the "cadron" or alphabetical dial system is principally used, and as its operation is simple and quickly learned, the station-masters or other employés are fully capable of managing it. In America, on the contrary, the instrument used is almost invariably the Morse sounder or embossing recorder, which, although more rapid, and, possibly, in the hands of skilled operators, familiar with its code, more satisfactory, requires, to be properly served, a much longer training and higher capacity. The record of the embossing Morse instrument is also much inferior to that of the ink-writer, so generally used in Europe, and the American code is much more liable to error than the European.

With us the railway office is, to a great extent, the school of the Morse operator, who leaves it as soon as he becomes proficient, to seek a higher salary with a telegraph company, and to divest himself of the opprobrium attaching among the fraternity to a railway "plug."

With the American Morse instrument and code, consequently, the ordinary telegraphic service on railways is either conducted at a large cost to the companies, or is left to the hands of unskilled employés, to the prejudice of safety. There may be circumstances in the condition and traffic of our railways which render it necessary that a minute knowledge of and control over the movements of trains should always exist in the central office: in other words, that the system of "train despatching" should continue. If this be the case, supposing, which is probably true, that the Morse is the instrument best adapted for such service, the railways should secure, at any cost, the best telegraphic talent. I am convinced, however, that when such exceptional circumstances disappear, as they will with the improvement of tracks and the more regular growth of business, it will be found to the interest both of economy and safety to adopt a simpler instrument for the general service, and to rely on special signals for the prevention of accident.

While the general use of the telegraph is to railways a convenience greatly augmenting their capacity for business, the employment of special signals, electric or otherwise, is a matter of necessity to the public, whose safety is at stake. As very few accidents are due to natural or inevitable causes, it follows that there must be somewhere responsibility for them, and it may be said that the surest method of preventing them would be to concentrate this responsibility upon some one person against whom penalties may be directed. To a limited extent this theory may be correct. Were the remedies of the law always obtainable, however, and always rigidly enforced, they could afford no adequate compensation for the terrible consequences of railway accidents. The policy of prevention must, therefore, be almost entirely dissociated from any idea of remedy.

In some European railways there are employed immense numbers of flagmen, at short distances, to protect the trains. Even if this were the best system, it would be obviously impossible to guard every step of a railway in America by human agency. Machinery of some sort must, therefore, be trusted to; and thus far electricity seems to offer almost the only practicable solution of the question.

The "special" telegraphic service, or railway signal system, as it exists in Europe (or rather on the continent), is very fully represented at the Vienna Exhibition, but the apparatus exhibited by the different countries is variously classified. In some cases it is placed in Group XIII., with "Machinery and Means of Transport," in others, in Group XIV., with "Philosophical Instruments," or Group XVIII., "Civil Engineering and Architecture," and still again in "Additional Exhibitions," such as those of the Austrian railways. Aside from this, the exhibits of different countries in the same group are so far apart that it has been exceedingly difficult to make a comparative examination. In many cases, also, there are no pamphlets or explanations accompanying the apparatus, and no one in charge to work or give information in regard to it. I have endeavored, however, to investigate as thoroughly as possible not only the systems represented here, but others which are not exhibited, and trust the result may not be without value.

In a recent French report upon this subject (*Resumé des conferences sur la telegraphie electrique, par M. Amiot,* *Inspecteur, etc.)*, railway signals were divided into four classes, as follows: —

1. For the "covering" of trains (i. e., to indicate by optical signals that a train has passed a signal-station and that another must not follow).
2. To signal the movement of trains (electrically).
3. To signal from trains in case of accident.
4. To communicate between the various portions of a train.

Having in view, however, the prime object of the signal-service, a more logical division of the subject would seem to be one based on the actual course of trains from station to station and the character of accidents to which they are liable.

Aside from those arising from the imperfect condition of the track or rolling stock of a railway, which can only be avoided by frequent inspection, the dangers to which trains are subject are principally occasioned by —

1. The displacement of switches or semaphores at stations.
2. Vehicles, etc., upon the track at common road-crossings.
3. Collision of trains in motion, following or meeting each other, on the same track or at junctions.
4. Causes within the train itself.

The signals themselves cannot be so readily classified as the dangers which they are intended to avert, inasmuch as some of the apparatus may be used with equal facility to attain several of the objects desired. For the purposes of this report, however, it will be sufficient if I explain their actual uses, merely suggesting others to which they may be applied.

From this stand-point (i. e., of the purposes they are designed to serve,) railway signals may be considered in six groups, viz.: —

1. Signals of the movement of trains.
2. Signals giving knowledge of or control over the position of switches or semaphores not visible to the person requiring such knowledge or control.

3. Signals of warning at grade-crossings of common roads.
4. Signals "covering" the position of trains in motion from trains following, meeting or crossing.
5. Signals between the various portions of a train.
6. Signals to be used in case of accident.

Through the first four of these classes runs a general, or rather a special subdivision, and one of great importance, if not to the present, at least to future systems of railway signalling. Until recently, signals between stations and trains in motion have been on the one hand purely optical, as the display of flags, lights or semaphores from stations, and on the other optical or aural, as the display of flags and lights and the blowing of whistles on trains. Since, however, it has been found practicable to communicate *electrically* between stations and rapidly moving trains, the possibilities of railway signalling have been greatly extended.

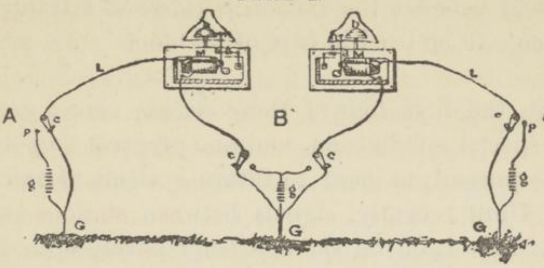
I. Signals of the Movement of Trains.

I have not thought it important to consider at much length the various devices employed to indicate from point to point the forward movement of trains. When there are special functions to be performed (and it is to such points only that I desire to apply the general term "station"), the stations are usually connected by the ordinary telegraph, and announcements of the arrival and departure of trains may, of course, be made in the ordinary manner by message.

In a purely "signal" service, however, each "station" and intermediate "signal-box" is on an equality with every other, and a method of communication is necessary which can be employed and interpreted by signal-men as well as by skilled telegraph clerks. This may be easily attained by making each such point the terminus of an electric "circuit," in which is inserted a "bell-sounder." This is an ordinary electro-magnet, the armature of which is extended upwards and furnished with a hammer, which strikes upon a bell when the circuit is closed. As this apparatus, though simple, forms an important part of many of the signals in use for other purposes, a brief diagram and description of it may not be out of place here.

To illustrate the arrangement of signal stations between which the movement of trains only is desired to be shown,—

PLATE I.



Let A, B and C (Plate I.) be three adjacent signal-stations, or boxes. A and C are, of course, fitted up exactly as B; but it being only necessary to describe one set of apparatus, those at A and C are omitted from the drawing. M M are magnets placed upon the lines L L, which, after passing through the coils of the magnets at A, B and C, are connected to the ground G, through the commutators, or switches, *c c c c*. In their normal condition, therefore, there is no electric current passing on the lines on either side of B. This is the ordinary arrangement of what is called an "open circuit." *

Suppose now that a train passes A, whose approach he wishes to signal to B. By turning the switch *c* to the left, the current from the galvanic battery *g* is thrown on the line through the point *p* and the switch. The magnet M, being influenced by the current, attracts the armature *a*, and the hammer *h* at the upper extremity of the armature strikes against the bell *b*. The stroke, of course, continues as long, and is renewed as often, as the switch is thrown upon the point *p*. The instrument is enclosed in a box, as shown in the figure, and placed against the wall of the station, or at any other convenient spot, the bell and armature being protected from exposure by means of a zinc cap *z*.

* Objection has been made to the use of the open circuit with one wire for signals, on account of the momentary signals which might be produced by atmospheric electricity seeking its way through the wire to the ground, or by what are known as "earth currents." But as the object of the above description is simply to illustrate the action of the "bell-sounder" under the influence of any electric current, these objections need not here be considered.

It only remains to devise a simple code of signals by strokes, in order to convey to the man in charge at B the necessary intelligence from A or C, and *vice versa*. The difference in tone of the bells indicates to the signal-man from which side the train is approaching. The number of strokes, and their combination, may inform him of the character of the train, whether freight or passenger, and of the company to which it belongs, in case the track is occupied by two or more companies. The agent is thus given from a distance all the information which is usually conveyed from the train itself on its near approach, by means of different colored flags, lights, etc. He has, therefore, ample time to make all necessary preparations, and on the passage of the train, signals its coming in like manner to his neighbor.

A system like this requires, as will be seen, the closest attention on the part of the signal-man; and it is usual to include in the code a sign of acknowledgment, without receiving which the signal is not regarded as complete by the sender. The direct action of the magnet upon the bell-hammer, which constitutes the simplicity of the above apparatus, practically limits the size of the bell employed to that of an ordinary office or dining-room call-bell. When it is necessary to sound a larger bell to attract the attention of a distant attendant, machinery must be introduced, in which electricity operates, not as the direct motive-power, but as an agent to release a mechanical force strong enough to produce the desired result. One of the best and most generally employed systems of this class is that of Leopolder, which is in use on the Nordbahn and other Austrian railways, and on the Northern Railway of Italy from Turin to Venice.

I am indebted to Mr. Leopolder, and to the *Allgemeine Telegraphenbau Gesellschaft* of Vienna, of which company he is a member, for a drawing of his apparatus.

The system is operated by opening instead of closing the circuit. When the apparatus is in its normal position the circuit is closed. The wires of the magnet are connected, one to the neighboring signal-station and battery, and the other to the ground. When the circuit is thrown open the current ceases to act on the magnet, and the armature, being no longer attracted, is drawn up by the tension of a spring attached to its lower arm.

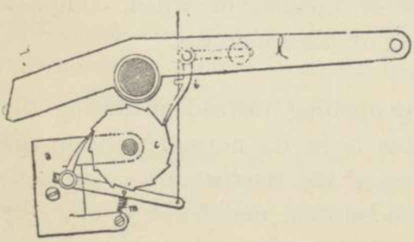
Fixed to the armature, on its upper side, are two arms which sustain a lever. On the rising of the armature and lever the latter releases a wheel which it allows to make one revolution, upon which it falls into its normal position. This wheel gears into a larger notched wheel, turned by a weight, the gears in such relation that the larger wheel advances one notch to each revolution of the smaller. These notches lift an arm having a hammer at its extremity, which strikes upon a large bell. It also operates another arm provided with a punch, which perforates a sheet of paper passing between rollers. The number of signals given upon the bell is thus accurately registered on the paper.

The registering part of the apparatus is called the "control," which term, however, is used in Europe indifferently, to designate a register of signals at the receiving station, or an automatic acknowledgment returned to the sending station. It is also applied, at least by the French, to the motive-power, or "controlling" force.

The system Leopolder, with the "control" attachment, is exhibited in the separate "Nordbahn Ausstellung," or collection of the Northern Railway of Austria. It having been introduced into Italy before the adoption of the "control," the latter was added, in substantially the same manner, by Sig. Montelli, one of the engineers of the Alta Italia Railway. In addition to this, however, a further modification was introduced by Sig. Montelli, and the apparatus, thus modified, is on exhibition in Group XIV. of the Italian department.

PLATE II.

A

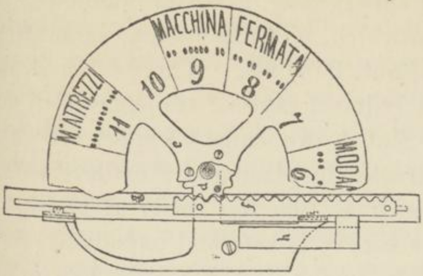


When the bell-lever *l* (Plate II., A) falls to deliver the stroke, it carries with it a catch *i*, which strikes against a tooth of the ratchet-wheel *c*, and carries it forward one tooth. The wheel is prevented from turning farther by a spring *a*, held against it by the tension of the spiral *m*.

The wheel *c* turns on the same axis as a cog-wheel *d* (B), the cogs of which, twelve in number, fit into those of a sliding bar *f*, *d* turns the large disc *e*, which is divided into twelve compartments or spaces, on eleven of which are printed the eleven code or dot-signals used on the Alta Italia Railway, with their meaning in plain Roman characters. The twelfth space is left blank.

PLATE II.

B



For every stroke on the bell, therefore, the disc is turned one space to the right, and the signal exposed at the top agrees with the number of the strokes. The attendant, hearing the sound of the bell, perhaps from a distance, comes to the signal-box, and having satisfied himself as to the signal, pulls a cord which releases the spring *a* (Plate A), and the disc, impelled by the weight *h* (B), falls to the position shown in the cut, with the blank space exposed at the top. The apparatus is simple, inexpensive, and little liable to error.

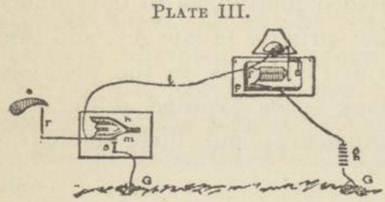
Messrs. Siemens & Halske, the widely-known electricians and instrument-makers of Berlin, have also, in their admirable collection, a similar apparatus to that of Leopolder, in which the control consists of an ink-writing Morse register. The apparatus is enclosed in a circular iron box surrounding the bell-support, and is so arranged, that on shutting the door of the box, the circuit is closed automatically should the person sending the signal have forgotten to close it.

The use of the foregoing apparatus presupposes the existence of a code, and this admits of its being employed, not only to signal the *movement* of trains, but also to give distress signals, which I have classed by themselves as Group VI., and, in a limited way, to answer the purpose of signals classed under Group II., or even, with a more extended code, of a speaking telegraph. There are two sets of apparatus, however, employed to signal the movement of trains, on which no code can be used.

The first of these belongs to that class of which I have spoken, as having such an important bearing on the future of railway signalling; i. e., electrical signals between stations and trains in motion. Although rude in its construction, and destined, doubtless, to be superseded by better methods, it illustrates the principle, on which, it seems to me, signalling in America must be carried out, if at all. Where labor is so scarce, and the demand for reduced rates of transportation so urgent as in the United States, we cannot expect railway companies to protect their tracks, by placing at short intervals, agents and signal-houses such as line the roads of Europe. Moreover, if the use of machinery is safe and expedient, the safest and best is that which, under proper guards, leaves as little to human agency as possible. I will not, however, enlarge upon this point at this stage of my report.

The apparatus alluded to is that employed by the *Compagnie du Nord*, near Mauberge, in France. It consists simply of a heavy spring or lever *a*, Plate III., securely fastened to the side of the rail in such a position as to be pressed down by the flange of a driving-wheel passing over it. The spring when depressed, pushes down a rod *r*, which is bent at right angles, and which carries at its end a flexible piece of metal *m*. This piece of metal which is connected with a line wire *l*, presses upon the standard *s*, which is connected to the ground. The arm of the rod *r* is attached to the under side of a small pair of bellows *b*, inclosed in a box beneath the track, as shown in the diagram. When the circuit is closed through *m* and *s*, the bellows is forced open, and closing only gradually, prolongs the signal given on the distant "bell-sounder," which would otherwise last only so long as the lever *a* is depressed.

PLATE III.



The bell is of the class known as the *sonnerie à trembleur*, or trembling-sounder. Its construction is similar to that of the simple "bell-sounder" before described, with this exception; that the circuit is arranged so that as soon as the hammer strikes the bell, it furnishes a shorter route for the current than through the helices of the magnet, or, as it is termed, "cuts the magnet out." The magnet ceasing to act, the armature is drawn back by the force of the spring. But this re-establishes the circuit through the coils, the armature is again attracted, and the hammer again strikes the bell. It is evident that the armature will continue to vibrate and the bell to ring as long as the circuit is closed at *m s*. The train thus announces its own approach by signal, which, it is true, lasts only as long as the train is passing, but which can be made permanent if necessary, by the introduction of a very slight modification in the apparatus.

The use of the lever at the side of the track was introduced in America, by Mr. Thomas Hall, in 1869, in connection with apparatus which will be hereafter alluded to.

The trembling-sounder, here described, fills an important place in the signal systems of Europe. On the continent, the law generally requires gates to be placed at grade crossings of common roads, which are shut for a certain time before the passage of every train. On some of the lines in France, the gatekeepers are advised electrically of the approach of trains by the use of the trembling-sounder, in order to close their gates. The attention of the gatekeepers, which might not be drawn in time for them to interpret any preconcerted code, is attracted by a continuous signal, which has but one meaning. As it is unnecessary that the gatekeepers should know either the character of the train or the direction from which it is approaching, a number of signal-boxes are sometimes placed on the same circuit and operated at the same time. The principal use of this arrangement is in the vicinity of towns, where crossings are near together. The signals, in the arrangement described, are of course sent from fixed stations. They are not properly "warning-signals," of which I propose to treat under Group III.

The trembling-sounder is again extensively employed throughout Europe for giving notice at stations of the position of outlying switches and semaphores, and it is, therefore, proper to introduce the second branch of my subject by a short notice of its application to such purpose.

II. Signals giving knowledge of or control over the position of switches or semaphores not visible to the person requiring such knowledge or control.

The apparatus classed under this head may be divided into:

1. Instruments simply giving *information* at a distance, by means of electricity, of the position of switches or semaphores, draw-bridges, etc.; and
2. Instruments by which the position of semaphores may be *changed or controlled* at a distance through the medium of electricity.

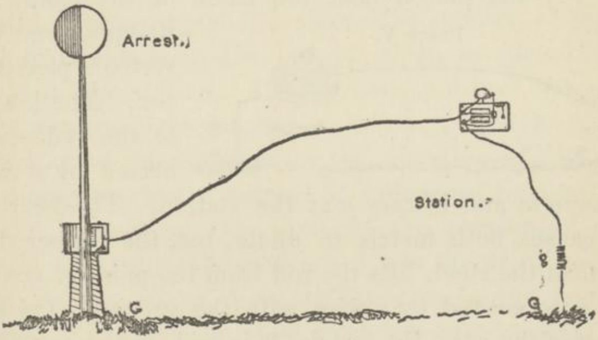
In technical parlance, the former are designated, both by French and German engineers, by the name of "Control." Since the introduction of the latter, however, a modification of terms would seem to be necessary.

While heavy switches are necessarily turned by hand, the lighter optical signals, consisting generally of a metal arm or disc placed at a convenient height at the side of the track, are frequently manipulated at a great distance from the stations by means of a wire running on pulleys at the top of posts some two feet above the ground. These semaphores are sometimes out of sight of the stations, and their position cannot always be known with certainty at the latter.

This arrangement, almost universal in Europe, has not been found of itself sufficient. When there are sharp curves in the immediate vicinity of stations, neglect of the signal-men to perform their duty or failure of the signal to work properly has been a not infrequent cause of accident. Still, on busy lines, where the position of semaphores (which are necessarily placed some distance outside the switches), must be frequently changed in pursuance of advices received by speaking telegraph or by signals of the first class, they must be manipulated from the stations. The danger thus presented (in case of breakage of the wire or other failure of the distant semaphore) to a train lying quietly at a station of being run into by another, has caused in Europe the very general introduction of electrical apparatus for its prevention.

The system of Mayer & Wolff, telegraphic instrument-makers of Vienna, which has been adopted and is exhibited by the Nordbahn Railway of Austria, is one of the simplest of this class, belonging to subdivision *a*. The semaphore is a disc of the ordinary class, which is turned from the station in the usual manner by a crank and wire. Around the support of the semaphore is a small circular box of metal, used to protect the connecting points of an electric circuit from exposure to the weather. As the semaphore turns to the position of arrest, a projection upon one side of the support touches within the box a brass spring, which is insulated from the semaphore and its metal support, and connected by a wire to the battery at the station. The support itself is connected with the ground, and thus an electric circuit is formed. Plate IV. illustrates the arrangement.

Plate IV.



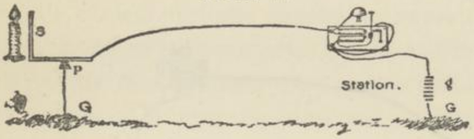
In circuit at the station is a trembling-sounder, which rings as long as the disc is in position of arrest and the projection on its support touches the spring. One of the advantages claimed for this particular apparatus is, that the bell does not commence to ring until the disc is very near the position of arrest, thus rendering false or accidental signals improbable.

Where the semaphore adopted is an arm instead of a disc, it is evident that by changing the position of the connecting points from the side of the support to the top near the fulcrum of the arm, the above system could be used equally well. In that case, however, inspection of the points, which is necessary from time to time in order to keep the connections perfect, would be more difficult.

The use of the foregoing or similar apparatus is the cause of that constant ringing of bell-signals which is so often noticed by the traveller in Europe while his train is waiting at a station. On the single-track routes of the *Compagnie du Midi*, in France, the discs were almost constantly in position of arrest. Hence, to avoid the incessant ringing of the bell, a simple method was devised by which the action of the apparatus might be suspended by hand at the station and reëstablished at pleasure.

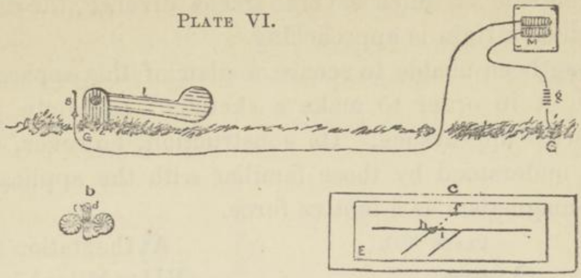
On the above line and also on the line of the *Compagnie de Lyon* a further modification of the apparatus was introduced. Signals at night being given by means of lights, it was thought necessary to keep the stations advised as to the condition of the light, which might by accident become extinguished, For this purpose a bent rod of steel *s* (see Plate V.) was placed near the flame of the lamp, and in its upper end was inserted a piece of copper. The lower arm of the rod was connected by a wire to the *sonnerie* and battery *g* at the station. The heat of the lamp causes both metals to dilate, but the copper dilating more than the steel, lifts the rod from the point of contact *p*, which is connected by a wire with the ground. On the extinction of the lamp the metals, it is said, in the course of fifteen or twenty seconds resume their natural dimensions. The lower arm of the rod falls on the point *p*, the circuit is established and the bell at the station rings. This apparatus is the invention of M. Boucher. Similar contrivances, the inventions of Messrs. Whitaker, Lewis, and others, with the thermometer attachments, have been patented in England. In the Italian department of the Exposition, near the model of the Mont Cenis Tunnel, is an apparatus employed by the Alta Italia Railway for showing to a station the position of anoutlying switch, which, although equally simple, is on a somewhat different principle from the foregoing systems.

Plate V.



The arrangement is shown in Plate VI. : *l* is the lever of the

PLATE VI.



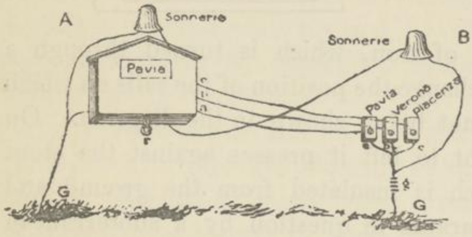
switch, a heavy piece of iron, which is turned through a semi-circle in order to change the position of the rails on which it acts, the connection not being shown in the diagram. On being turned from right to left it presses against the stout metallic spring *s*, which is insulated from the ground and connected (in the apparatus in question by a subterranean wire) to the magnet M, and through it to the battery *g* at the station. The switch-lever being connected with the ground, thus closes the circuit of the battery, which acts upon the electro-magnet. *b* shows the position of the magnet M as it stands in the box *c*, which is placed against the wall of the station. Between the poles of the electro-magnet a permanent magnet *d* is hung, with its poles so arranged as to be attracted in the direction of the dotted lines when the electro magnet is influenced by the current from the battery *g*. The axis of the permanent magnet is carried up through the card-board E to the point *h*, where a needle *i* is secured to it at right angles to the permanent magnet *d*. The position of the main and side tracks is traced on the card-board.

The apparatus being thus shown, its operation will be easily understood. As soon as the switch-lever is thrown over to change from main to side track, it presses against *s*, closing the circuit. The electro-magnet M attracts the permanent magnet *d*, which swings from left to right, carrying with it the needle *i*, which is thrown over to the point *f*. The position of the switch is thus indicated in the clearest manner at the station.

There is another interesting and useful instrument in the Italian department, employed on the upper Italian railway for the purpose of indicating to their principal stations from points outside at which several tracks diverge, the direction from which a train is approaching.

Having been unable to secure a plan of this apparatus, or to open it in order to make a sketch, I can only present its external appearance. Its construction, however, will be readily understood by those familiar with the application of electro-magnetism as a motive force.

Plate VII.



At the station A Plate VII. (Milan) is an apparatus consisting of a *sonnerie à trembleur* and a flat case or box hung on the wall in the office of the station-master. The case is connected by three wires to three circuit-closers *a*, *b* and *c* at the junction, and by a fourth to a *sonnerie* which serves as a "control" for the signal-man.

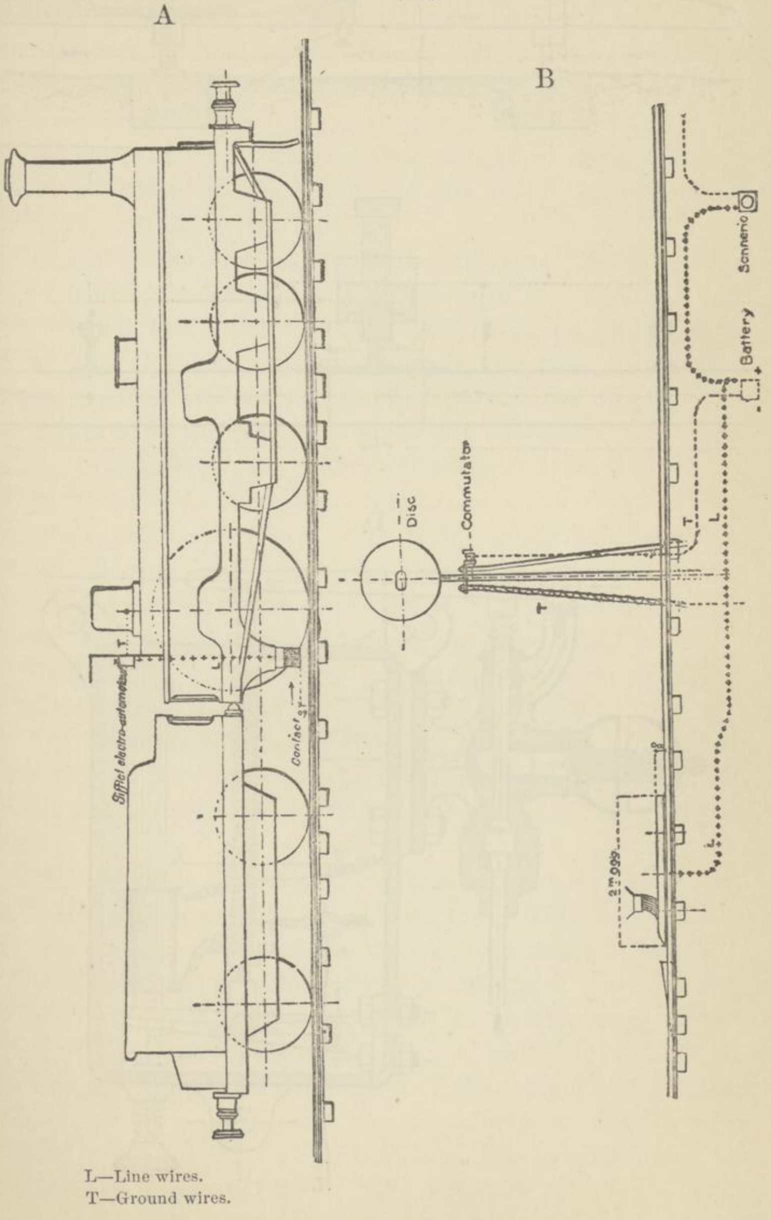
On the arrival of a train, say from Pavia, the signal-man presses down the button at *a*, throwing the current from the battery *g* upon the line. The circuit is through an electro-magnet in the case, thence through the magnet of the trembling-sounder to the ground. The magnet in the case turns a disc so as to display the word "Pavia" at the window of the case, and at the same time the *sonnerie* rings, attracting the attention of the station-master. The latter, by putting down the ring *a*, returns the disc to blank, arrests the ringing of his own bell, and at the same time closes the circuit of the fourth wire to B, thus indicating, through the *sonnerie* at that point, that the signal has been received and understood.

The battery *g* may of course be placed at the station as well as at the junction.

I have been much indebted to the courtesy of Sig. Orestes Lattes, an engineer of the Alta Italia Railway, and a member of the Italian Commission and International Jury, for facilities given me for the examination of the interesting exhibit made by his company.

An apparatus of a totally different character from the others of this class, and in some respects of entirely novel construction, has been lately adopted by the *Chemin de fer du Nord* of France, and is exhibited in the case of the *Administration des Telegraphes*, in the French department, with other apparatus of the same manufacturers, *Digney frères*, of Paris. It

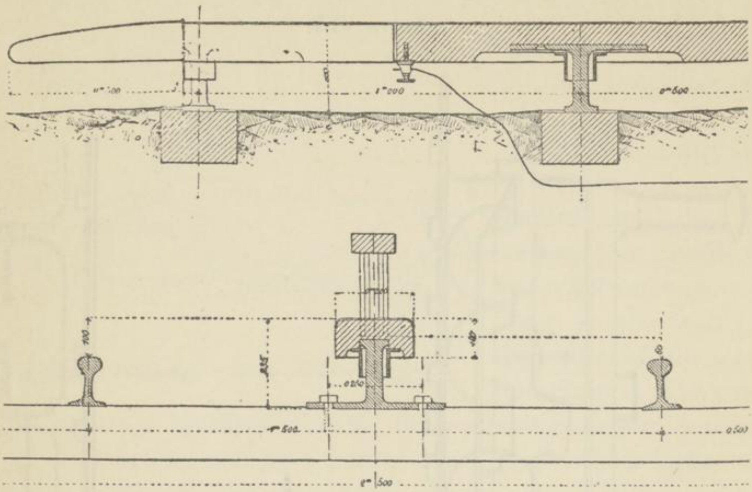
PLATE VIII.



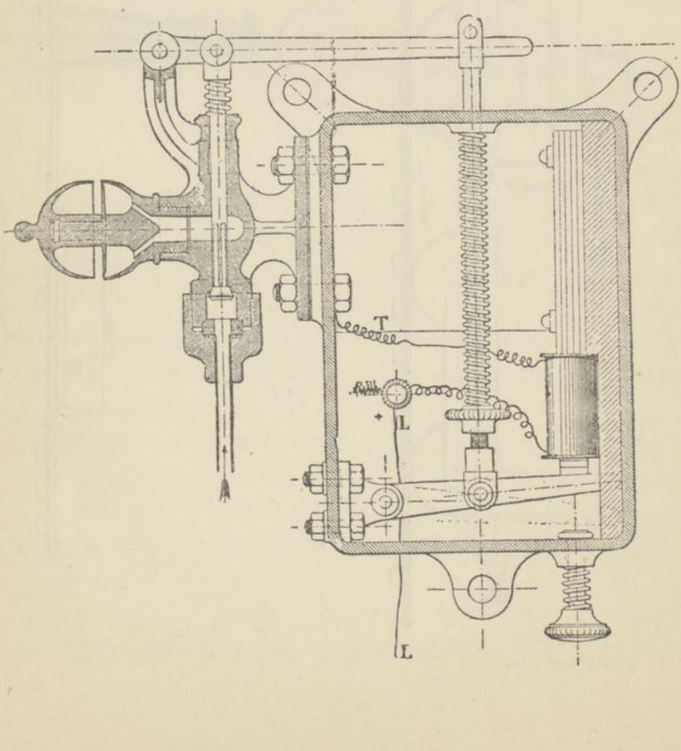
L—Line wires.
T—Ground wires.

PLATE VIII.

C



D



is called the "*Sifflet électro-automateur*," or Electro-automatic whistle, of Messrs. Lartigue & Forest. Its object is, by blowing the whistle of a coming train, to warn it of the position of a switch or optical signal which it is approaching, but which, by reason of fog, heavy snow, or even rain, or the extinction of a lamp at night, cannot be seen by the engineer. It belongs, therefore, to the class of signals between stations and trains in motion, to which I have alluded, and is a step in advance of all the apparatus just described in Group II, which give notice of danger, it is true, but whose warnings may, by reason of the distance of the switch or semaphore from the station, arrive too late.

The invention consists of two essential parts, the first being the means by which contact with the train is established, and the second the apparatus employed to sound the whistle. While in this particular instrument the two are coupled together, it is evident that the first part of the invention, if, as seems to be the case, it is uniformly successful in its operation, is capable of very wide application. I am assured by French engineers that the contact has never failed during nearly a year's experience, with trains going at a speed of sixty miles an hour (which is very often attained by the London express), and with the ordinary obstructions of snow, dirt, and even heavy ballast, upon the track.

Plate VIII., on preceding pages, represents the apparatus which is thus described.

Fig. A shows the locomotive and the manner of making contact; B, the connections to the distant semaphore; C, the fixed contact-plate, and D, the whistle upon an enlarged scale.

The whistle is of brass, in communication with the boiler, and carried in a metallic box on its top. This box contains a lever parallel to that of the whistle, to which it is attached. This second lever is influenced by a stiff spiral spring, which tends to lower it, and consequently to let the vapor escape. It carries at its extremity, however, an armature of soft iron in contact with an electro-magnet of the "Hughes" pattern, composed of a permanent horseshoe magnet, the arms of which are prolonged by cylinders of soft iron surrounded by helices of silk-covered wire. The cylinders become the poles of the magnet, and their attraction counterbalances the action of the spring.

If a current of electricity is made to pass through the helices in a certain direction the armature is momentarily repelled, the lever falls, and the whistle sounds until the engineer, by pressing on a button which is shown on the under side of the box (Plate D), arrests it in returning the lever to its original position (i. e., in contact with the magnet).

The current of electricity is produced in the following manner: —

The wire of the magnet is connected on one side with the body of the engine and by the intermediary of the wheels and rails with the ground. The other extremity is prolonged by a wire which, descending under the engine, is connected to a *metallic brush*, insulated and fixed in such a position that the end is lower by several centimetres than any projection on the engine.

This brush (Figs. A and B) is composed of stiff brass wires, of about No. 8 gauge, strongly set in an insulating substance, but terminating at their upper ends in a brass plate, which is again protected on the upper side by insulation. The connection is made by wire to this plate.

On the track, at any desired distance from the disc or semaphore, is placed a "fixed contact," composed of a piece of wood (see Fig. C), placed longitudinally between the rails and supported by iron standards at such a height as not to be touched by any projection on the engine.

This piece of wood, covered with an insulating compound, has on its upper surface a sheet of brass, which, by means of a wire of any desired length, is placed in communication with the positive pole of a galvanic battery (see Plate B). The negative pole is connected to a commutator fixed on the semaphore in a manner similar to that used in Mayer & Wolff's system (see Plate 4), which connects it with the ground when the disc is turned to "arrest." (The "*sonnerie*" shown in Fig. B is the station-alarm, and has no connection with this apparatus.)

On the passage of the engine the brush presses strongly against the fixed contact. If the distant semaphore is at "line clear," there is no effect produced. If, on the contrary, it is turned to "arrest," the sheet of brass is in communication with a source of electricity, and, on the passage of the locomotive, the metallic brush completes the circuit through the helices of the magnet, the armature is repelled, and the whistle is made to sound in the manner described.

This apparatus is said not to have been at all deranged by the shock of contact, and the brushes, after eight months' usage, show scarcely any traces of wear.

The contact between the rails is the one adopted by the *Compagnie du Nord*. Where very heavy snow-falls or other obstructions are to be feared, however, the contact might easily be placed at the side of the engine, at a convenient height from the ground.

It was feared, at first, that owing to the speed of trains the contact would not be sufficiently lasting to produce the desired effect, and accordingly the first trials were made with fixed contacts of over four metres in length, which permitted a contact lasting from one-fourth to one-fifth of a second at the highest speed. It was found, however, that a length of two metres in a fixed contact was sufficient to give the necessary signal, and this is the length adopted.

Various applications of the apparatus (in its entirety) are suggested by the inventor, not only for railways, but for the service of mines and the marine. The important uses to which the contact alone may be adapted will probably suggest themselves in the course of the following pages.

The apparatus of Group II, above described, is employed for the purpose of giving information merely of the position of a switch or semaphore. We now come to subdivision *b*:—

Instruments by which the position of semaphores may be *changed or controlled* at a distance through the medium of electricity.

Mr. W. H. Preece, the well-known Superintendent of British Postal Telegraphs, himself the inventor of a very ingenious system of signals, which will be hereafter described, says, in an able review of this subject, published in 1865: "If it were possible to work an out-door signal by electricity the system would be perfect, but inasmuch as the power of electricity is but circumscribed, we have not yet attained that production of force which is necessary to actuate with any degree of certainty our exposed signals. We are, therefore, compelled to adopt the nearest approach to this, and to rely upon small electrical instruments, which direct the signal-man how to exhibit his out-door signals by displaying the signals which they themselves ought to give."

Since the date of the above, the difficulties alluded to have been ingeniously overcome by several inventors. In the number of apparatus the Austrians, so far as I know, have taken the lead. They have, in fact, the only instruments of this class at the Exhibition. It is only recently that electrical signals for such purposes have been permitted in Austria. There are now, however, two systems in operation, and a third is completed and shown at the Exposition.

The first of these is that of Mr. Hohenegger, an engineer of the Nordwestbahn, by which company the signal is exhibited and employed. It is also used on some roads in Hungary.

I am indebted to Mr. Hohenegger for a diagram of the apparatus which is shown in Plate IX. The machinery is in many respects similar to that of the system Leopolder, page 441, but its adaptation is so different and so interesting that it merits a separate description.

Plate IX. A shows the external appearance of the semaphore, looking down the line; B, page 458, the internal apparatus, and C the connection to the station.

The arm of the semaphore moves through an arc of forty-five degrees, and carries on its left extremity a smaller arm, in which are set two circular pieces of glass, one red and the other green, which pass in front of a fixed lantern, accordingly as the arm is raised or lowered. The lamp is raised to its position by means of a chain shown in the figure. At night, therefore, a red light signifies that the line is clear, and a green one that it is blocked.

The source of electricity is a magneto-electric or induction apparatus (Plate C), which is placed at the station. The slightest turn of the crank produces a sufficient current to operate the semaphore. To prevent accidental signals, therefore, the circuit is broken at *a*, and it is necessary to depress the button *a* (which is set even with the surface of a

Plate IX.

A

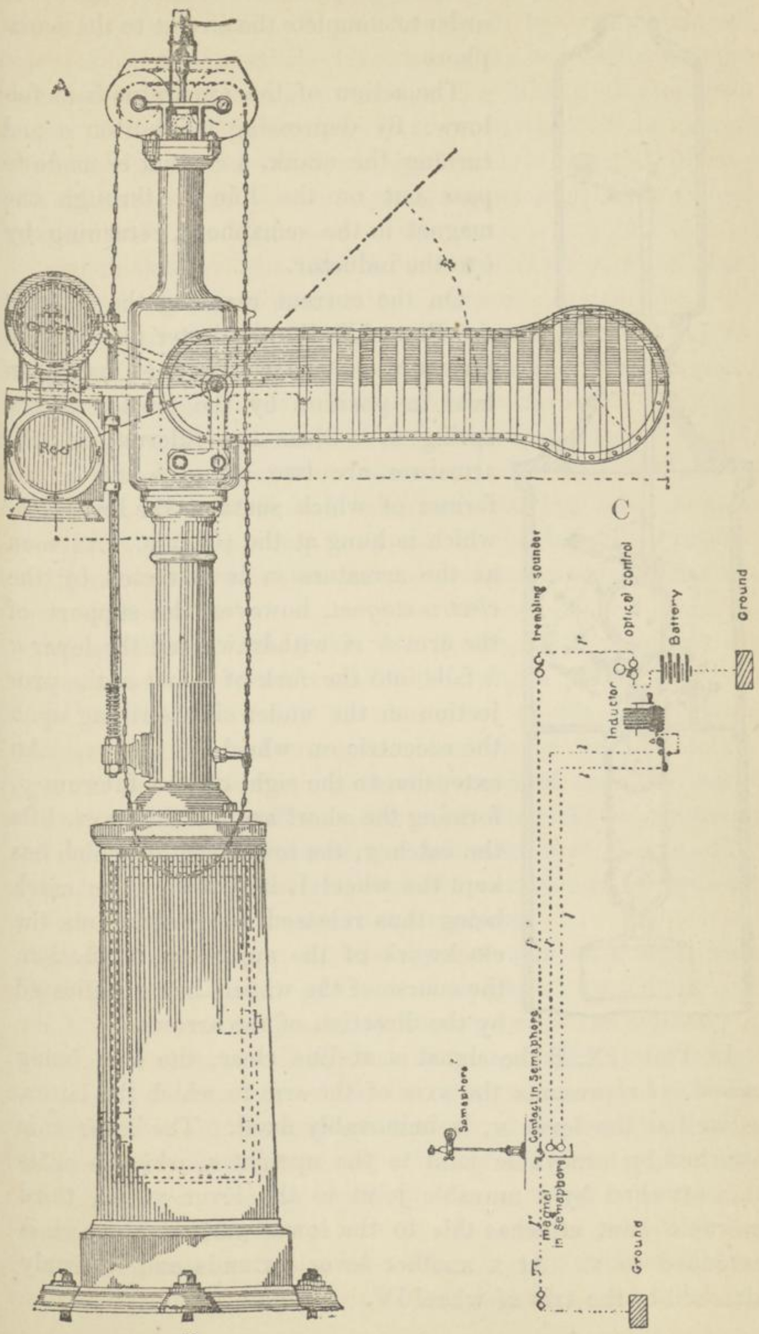
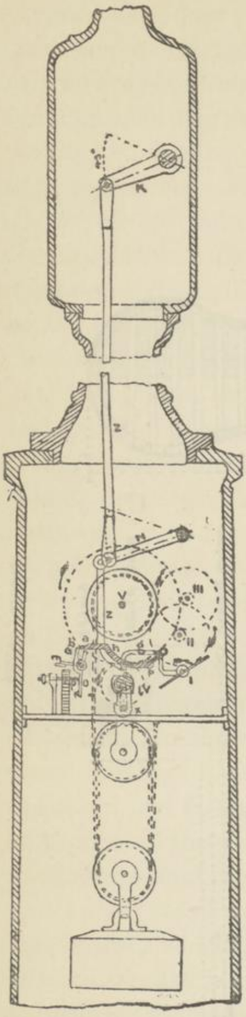

A
Green
Red
C
trembling sounder
optical control
Battery
Ground
Inductor
Semaphore
Contact in Semaphore
magnet in Semaphore
Ground

Plate IX.
B



small box upon the table, and can only be moved by pressure of the finger) in order to complete the circuit to the semaphore.

The action of the apparatus is as follows: By depressing the button *a* and turning the crank, a current is made to pass out on the line *l*, through the magnet in the semaphore, returning by *l* to the inductor.

On the current reaching the magnet (*f* Plate IX. B), the latter attracts the armature *m*, which until then has been held in position by the tension of the spring *o*. Near the fulcrum of the armature are two arms, *b* and *c*, the former of which sustains the lever *a h*, which is hung at the point *p*. As soon as the armature *m* is attracted by the *electro-magnet*, however, the support of the arm *b* is withdrawn and the lever *a h* falls into the fork of *b* and *c*, the projection on the under side striking upon the eccentric on wheel IV. below. An extension to the right of the fulcrum *p*, forming the short arm of the lever, lifts the catch *g*, the lower arm of which has kept the wheel I. in arrest. The catch being thus released, the weight sets the clockwork of the apparatus in motion, the course of the wheels being indicated by the direction of the arrows.

In Plate IX. B the signal is at line clear, the arm being raised. *l* represents the axis of the arm to which the latter, as well as the lever K, is immovably fixed. The lever K is attached by a movable joint to the upright Z, which is in its turn attached by a movable joint to the lever N. A third movable joint attaches this to the lower part of Z, which is extended to X. At X another lever extends and is firmly attached to the axis of wheel IV.

As wheel IV. revolves, therefore, in the direction of the arrow, the upright z is raised, and the semaphore lowered to "arrest." At the end of a half turn, however, the eccentric on wheel IV. has raised the lever *a h* to its original position. There being no longer any current passing through the electro-magnet *f* (for, as I have said, the slightest turn of the crank is sufficient to set the machinery in motion), the spring *o* lifts the armature *m*, and the arm *b* again supports the lever *a h* at the point *a*.

An instant after, the bent arm of the catch *g*, which has been kept in its raised position by a second eccentric on wheel IV., falls into the notch. The lower, or straight arm of *g*, is thus raised, intercepts the wheel I and blocks the machinery. The joint X is now above instead of below the wheel IV., and the semaphore is maintained at the position of arrest.

It is evident that another current of electricity will again release the clock-work, and the wheels moving again in the same direction, will bring the apparatns back to the position shown in the diagram, and change once more the position of the semaphore.

The number of times this can be repeated, depends, of course, upon the distance which the weight has to descend before "running down." In almost all of the signals yet constructed, the clock-work has been placed by Mr. Hohenegger at the top of the apparatus, instead of near the base, as here represented. The construction here shown has been lately adopted on account of the difficulty in winding up the apparatus at such a height, but the change has, of course, rendered more frequent attention necessary.

The use of two wires in this signal, which on a short line would not be a matter of much moment, on longer circuits would, of course, add greatly to the expense of the apparatus. Its object is to avoid the giving of false signals by lightning or "earth currents," to which the system would be liable if the earth formed part of the circuit. I do not think this danger sufficient, however, to justify, or rather to require the use of a second wire in case of the signal being employed at a considerable distance.

It will be seen by reference to Fig. C, that a third wire is employed for what I suppose must still be called the "control," i.e., for notifying the station that the semaphore has obeyed the current from the induction apparatus. The connections of this third wire are not shown in the plates representing the semaphore. They are easily understood, however, by reference to previously described apparatus. When the arm of the semaphore falls to "arrest," it closes a galvanic circuit which rings a "trembling-sounder," and also actuates a magnetic needle, or "optical control," at the station. An atmospheric current would, of course, act upon these control signals, but its influence would be only momentary.

The use of this third wire, which is connected to the earth in the ordinary manner, is necessitated by the employment of the other two, forming a complete metallic circuit. All of the operations, including the "control," might be performed on one wire, and, it seems to me, with entire safety—certainly in carrying out the particular purpose for which this signal is used at present. This, it must be remembered, is the prevention by optical signals, of collision at a station, and the particular danger to be apprehended is that the signal may be accidentally changed, not from "line clear" to arrest, as that would only produce delay, but from "arrest" to "line clear."

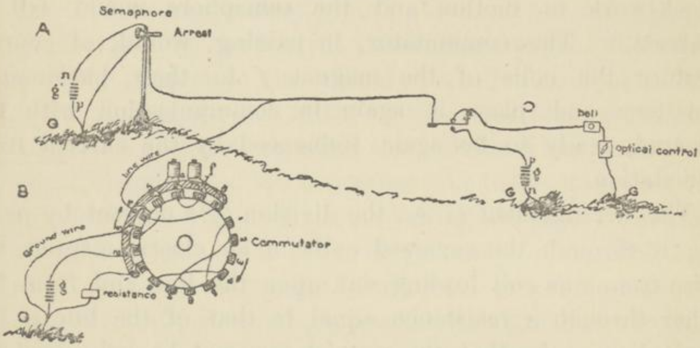
Now, a cardinal principle of every signal system should be, as Mr. Preece has well expressed it, "that any derangement of the apparatus, or the accidental delivery of a false signal, shall at once indicate danger and produce safety." The use of the third wire only prevents the "accidental delivery of a false signal." If, therefore, the system of Mr. Hohenegger could be so arranged as to carry out this object with one wire, the other two would become superfluous.

At present, the bell at the station sounds when the arm of the semaphore is at "arrest," thus indicating to the station-master that the signal is performing its duty and stopping approaching trains. Suppose, now, there were only one wire from the station to the semaphore, operated by a galvanic instead of an induction current, and having the ends connected to earth in the ordinary manner. A diagram (Plate X.) will perhaps best illustrate the position of the apparatus.

A train being at the station, the station-master presses down the button *a*, throwing the current of the battery *g* upon the line, setting the clock-work in motion and bringing the semaphore to arrest, which is the position of the diagram. The button *a* returns, of course, to its normal position, there is no current upon the line after the signal is given, and the "control" signals remain quiet.

Now, if an atmospheric current comes upon the line, it discharges itself in the earth, influencing, of course, both the "control" signals at the station and the magnet *f* of the semaphore (Plate VIII., Fig. B), both of which, however, are protected from damage by "lightning-arresters." The magnet *f* turns the signal up to "line clear." The object now would be to advise the station-master, who may not notice the momentary signals given by the lightning upon his "control," of the

PLATE X.



dangerous position of the semaphore, as he is advised, under the present three-wire system, of its proper position at arrest; namely, by sounding continuously his "control-signal." The same amount of attention which he now gives to the "control" to assure himself that the semaphore is in the proper position, would, of course, suffice if the "control" were used to warn him of danger.

Suppose the commutator of the semaphore, instead of, as at present, closing an extra "control" circuit when the arm is turned to arrest, were, *when the arm is turned to "line clear,"* to break the direct connection of the magnet *f* with the ground and to bring in circuit an extra battery, g^1, at the same time *reversing the direction in which its current should pass around one of the coils of the magnet f* and throwing the current through that coil, by way of a *resistance equal to that* *of the line to the station*, into the ground. The current from g^1, dividing equally between the two coils of the magnet *f*, passing in one direction through one and in the opposite direction through the other, would not affect that magnet.

It would, however, ring the bell at the station and attract the attention of the station-master, who would hasten to set the semaphore again at "arrest." By pressing down the button *a*, he would bring the station battery in circuit. The current from this battery, added to the half of that from g^1, circulating in the coil of magnet *f*, which is attached to the line, would overcome the contrary influence of the other half of the current from g^1, which passes in the opposite direction through the other coil of *f* and the artificial resistance, to the ground; the magnet *f* would again be influenced to set the clock-work in motion and the semaphore would fall to "arrest." The commutator, in passing, would, of course, restore the coils of the magnet *f* to their harmonious relations and place it again in communication with the ground, ready to be again influenced by the current from the station.

This arrangement (i. e., the division of a current by passing it through the reversed coils of an electro-magnet, the wire from one coil leading out upon the line and from the other through a resistance equal to that of the line to the ground, in order that the magnet may not be influenced by its own, but only by a distant battery), is the principle of the duplex telegraph of Mr. Stearns, now quite extensively employed in America.

A rough sketch of the commutator suggested is shown at Plate X.

A wheel, turning in the direction shown by the arrows and making a half turn for every signal, is added to the clock-work in the semaphore. It is furnished with sixteen insulated metal cogs, connected to each other by wires, as shown in the diagram. Above and to the left of the wheel is a semi-circular band, on which are secured eight insulated metallic springs, which press against the cogs and connect them to wires leading in the different directions shown. The wire from spring No. 1 leads to the resistance coil and ground, No. 2 to the extra battery g^1 and ground, No. 3 to the ground direct, and No. 4 to the main line from semaphore to station. Nos. 5, 6, 7 and 8 are attached to the ends of the coils of the electro-magnet *f*, by which the clock-work is put in operation.

The arm being at the position of "arrest," the circuit from the line wire passes through springs 4 and 8 (their corresponding cogs being connected) to one coil of the magnet *f*, thence by 7 and 6 through the other coil of the magnet in the ordinary direction, thence through 5 and 3 to the ground.

If now a current is put on at the station, or comes accidentally upon the line, the clock-work is released, the wheel makes a half revolution and brings the cogs numbered from 1 to 8 opposite their respective springs. The circuit may then be traced from the battery g^1 to 2, thence to 6 and 7, where it divides, part of the current passing through the right hand coil of the magnet in the ordinary direction to 8 and out on the line, ringing the bell at the station, and the rest going in the opposite direction through the left hand coil, back to 5, thence through 1 and the resistance coil to the ground.

A simpler method of accomplishing the same object, if practicable, might be to have the commutator merely cut out one coil of the electro-magnet *f* when the arm is thrown up to "line clear," and so to proportion the strength of the batteries g^1 and *g*, and the resistances of the magnet *f*, and that employed for the "control" bell, as to permit the extra battery g^1 to sound the bell without being able to influence the magnet of the semaphore through one coil. The battery *g* coming in aid would add sufficient strength to the current to draw down the armature of the magnet *f*, release the clock-work and restore the semaphore to "arrest."

The use of these or similar contrivances in systems of distance signals worked by electricity and clock-work would save the expense of two wires, and, in the Hohenegger system, of an induction apparatus. The cost and care of an extra battery at the semaphore would be added. The consequences of atmospheric electricity would not be avoided, but rendered harmless by the prompt alarm sounded at the station. Of course, when the signal is accidentally changed from "line clear" to "arrest," no damage, but only delay, is occasioned.* The danger arising from derangement of apparatus is to a greater or less extent inherent in any system.

I am indebted to the Allgemeine Telegraphenbau-gesellschaft, of Vienna, for a drawing of the apparatus of Mr. Schönbach, an engineer on the Westbahn, by which railway the system is employed and exhibited.

The construction is identical with that of the system Hohenegger, with this exception, that the upright lever, instead of raising and lowering a semaphore arm, is used to turn a wheel with a toothed axle. The teeth of the latter fit into the cogs of a horizontal wheel, the axle of which is extended upwards and attached to a circular disc, which it turns half round whenever the clock-work is released by the magnet.

Herr Ritter von Bergmüller, of Vienna, exhibits a third signal of this class, which is of much cheaper construction than the others, the clockwork being all of iron. The armature moves horizontally between the two poles of the electro-magnet, releasing a series of catches controlling the clock-work, which turns the disc of the semaphore. The winding apparatus is in the same position as in the Hohenegger and Schönbach systems, but the weight descends several feet below the ground, giving it a fall of perhaps six feet. Herr von Bergmüller states that seven signals can be given for every inch of the weight's descent, so that it needs to be wound up once for every five hundred signals.

In 1866, Mr. Thomas Hall devised a method of connecting an electric circuit with a switch or drawbridge in such a manner that when the rails of the track were displaced the circuit would be closed thereby and a danger-signal shown by means of a semaphore, operated by an electro-magnet, while at the same time a continuous alarm would be sounded

* In bell signals, on which a code is used, the danger of atmospheric electricity imitating or changing the signals is very slight; where the trembling-sounder is employed, a continuous ringing cannot be produced; and where a signal is given by and the "control" returned to a train in motion, as might be done by combining the automatic whistle with any of the systems in Group II. *b*, the intervention of lightning at the moment of receiving the "control" is exceedingly improbable. If in all of these cases, however, delay only and not danger is occasioned, its rare occurrence would be more than compensated by the saving in wires.

by a vibrating electric-bell at one or more points. This was put in successful operation within a year or two at several points on the New York and New Haven, and other roads. The semaphores consisted of a disc of colored cloth, stretched over a hoop and placed upon one end of a swinging-lever, the other end being provided with a counter-balance, and the disc is displayed by means of an electro-magnet, the armature of which was connected by a series of compound levers with its axis.

Mr. Frank L. Pope, the well-known electrical engineer of New York, has kindly furnished me with a drawing and description of his new signal, which, although not on exhibition at Vienna, has taken the first prize at the Cincinnati Industrial Exposition, and is already, if I mistake not, in operation on several American railways.

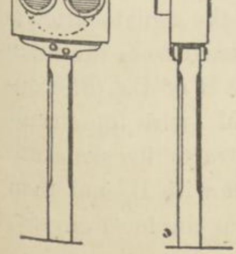
The signal is based on a different principle from any yet described, except that of Mr. Hall. It uses but one wire for the signalling and "control," and has in this respect a decided advantage over the European systems.

It also dispenses with all clockwork, using the direct force of electro-magnetism to turn the disc. This too, I doubt not, gives the system considerable advantage as regards both first cost and cost of maintenance or attention. The first cost of the European systems, however, I have found it impossible to obtain, in most cases, with any accuracy, and even were it obtainable, the prices here would afford no criterion of the cost in America.

For ingenuity of construction in an electrical point of view, also, the system of Mr. Pope far surpasses any of those heretofore described.

PLATE XI.

A



B

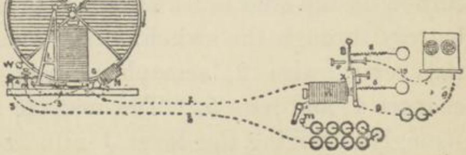


Plate XI. illustrates the appearance and working of the apparatus.

The external appearance of the semaphore is shown in Fig. A. It is placed on a post at the right-hand side of the track, at a suitable height from the ground; the signal is exhibited through two openings, each twelve inches in diameter, covered with glass, and illuminated at night by a lamp fitted with a reflector at the back of the signal-box.

The interior mechanism of the semaphore is shown in Fig. B. D is a disc about thirty inches in diameter, divided into four quarters, alternately white and red. An adjustable counter-weight, W, attached to the periphery of the disc, keeps it in the proper position to show red, indicating danger, except when under the influence of the electric current. Thus a white signal can only be shown when the machinery and battery are in perfect working order.

The disc is made to turn through one-fourth of a revolution by means of an electro-magnet M, the armature of which is attached to the short arm of the angular lever L, having a fulcrum at *l*. The long arm of this lever is connected by the pitman P with the crook K on the axis of the signal-disc. Thus the disc will turn and show a white signal whenever the magnet M is charged by the electric current. N is a supplementary magnet for locking the signal in position, when set white, as hereinafter explained.

The apparatus at the station may be at any required distance from the semaphore. It consist of a secondary or station-signal, which in principle and external appearance is a miniature copy of the distant semaphore—a differential relay, a signal-switch for operating the semaphore, and a main and also a local battery. In most cases a portion of the main battery may be employed to do the work of the local.

The operation of the apparatus is as follows: If it is desired to set the distant semaphore *white*, the signal-switch is turned on the stud *m*; a circuit is thus formed from the main battery through the switch, wire 1, magnet R of the differential relay, wire 2, semaphore magnet M, wire 3, circuit charger 4, and wire 5. The magnet R attracts its armature strongly, bringing the lever J into contact with B, and then forcing the latter against the stop *e*, so that the local circuit, which operates the small signal, is broken at z, notwithstanding it was at the same instant closed at x.

At the same time the magnet M turns the semaphore disc D in the direction shown by the arrow. Just before the disc D completes its movement, and after the white signal has been fully exhibited, a projection at o, on the lever L, comes in contact with a corresponding projection on the circuit-charger 4 and lifts it up, breaking the previously existing electrical contact at n. This cuts the battery current off from the magnet M and instantly transfers it to the locking magnet N. This occurs just as the soft iron armature Q on the disc comes in contact with N, and the latter being now strongly magnetic, seizes Q with great force and locks the signal disc firmly in its new position. The magnet N is, however, wound with a much finer wire than M, and the insertion of this great amount of extra resistance in the circuit weakens it to less than half its original strength in the relay R. When this occurs, the spring S, which is adjusted with a strong tension, pulls the lever J away from the relay-magnet until it is itself arrested by the stop z. At this juncture the local circuit is completed through wires 8, 9, and 10, and levers B and J, and the station-signal turns to white also, respecting the movement of the semaphore.

It will be seen that the system of Mr. Pope, which requires a permanent current to maintain the semaphore at "line clear," entirely avoids the danger from atmospheric currents, which seems to have been a bugbear of European systems, and that it fulfils as completely as possible the cardinal condition of Mr. Preece, that "any derangement of the apparatus, or the accidental delivery of a false signal, should at once indicate danger and produce safety."

Were it required to deliver the signal from a passing train, the object might perhaps be accomplished by substituting for the magnet M a magnet such as that used for the automatic whistle (Plate VIII.), the armature of which should be attracted by the combined force of the permanently magnetized cores and of a current of electricity sent in one direction, and again repelled (on the arrival of the train at a second contact where the semaphore should be changed) by the combined force of the spring and a current sent in the opposite direction.

The locking-magnet N could be placed on a local circuit, to be opened and closed at *n* by the lever L. As a very slight weight would be sufficient to keep the disc in position of "arrest," a slight force in the locking-magnet would seem to suffice to counterbalance it, and this force would be easily overcome by the stronger impulses given to the armature through the large magnet M. In this case the latter would be wound with small and the locking-magnet with large wire.

III. Signals of Warning at Grade Crossings of Common Roads.

There are no signals of this class on exhibition at Vienna, but the subject is too important to be passed over in a review of railway signals. Ordinarily in Europe, as I have said, gates are required to be kept at the crossing of highways, and they are generally closed in obedience to electrical signals sent from fixed stations.

The use of gates may be the only means of securing safety to those who cannot or will not take heed of optical or aural signals, and assure themselves that no train is near before crossing the track. Where signals are sent from fixed stations to the persons in charge of the gates, the large number of attendants required along a line where grade crossings are frequent, is a source of great expense to the railway. If several crossing signals are connected in one circuit, as is sometimes the case in France (see signals, class 1), an unnecessary delay may be caused to traffic on the highway.

The employment of gates is, therefore, not always desirable, or even practicable, in America. The frequency of accidents shows, however, that the means of prevention at present employed are not sufficient. When casualties of this kind are not due to the wilful carelessness of the traveller on the highway, they are generally occasioned either by his inability to see the approaching train or hear its signal, or by the neglect of the engineer to sound its whistle or bell in time.

What is wanted, therefore, is an aural or optical signal (or both), *placed at the crossing*, which shall be sounded or displayed without the aid of attendants whenever a coming train reaches a certain distance from it, and shall continue to sound or be displayed until the train has passed.

In 1869 Mr. Hall patented a method of using his signal and alarm apparatus, before described, at highway crossings, the electric circuits in this case being controlled by the moving train, through the agency of levers placed in close proximity to the rails, and in such a position as to be depressed by the wheels of the train as it passed.

This object may also be accomplished by means of a combination of the "automatic whistle" contact with a "*sonnerie*," and, if necessary, with a Pope's or Hohenegger's semaphore.

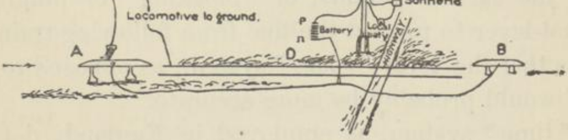
In case both the *sonnerie* and the semaphore are employed, the latter only need be actuated by the momentary current, and the arm or disc may be used to close a local circuit which shall actuate the *sonnerie* until the semaphore is again changed.

If the aural signals are thought to be sufficient, then a relay must be introduced like the magnet of the "automatic whistle," the armature of which shall keep the secondary circuit of the *sonnerie* closed until a current in the opposite direction to the first, reverse the position of the armature.

If the automatic whistle, as well as its brush contact, were employed on the engine, it would serve, of course, as an additional alarm to the traveller on the highway, and would warn the engineer as well that he was approaching a crossing.

Plate XII. shows the arrangement of the circuits for both a *sonnerie* and semaphore signal. The Hohenegger semaphore is shown, that being adapted to momentary signals; with some such modification as that suggested, however, the Pope system could be used equally as well.

Plate XII.



The train approaching in the direction shown by the arrows, closes at A the circuit of the semaphore, which, turning, closes the local circuit of the *sonnerie*. Then passing the crossing of the highway and touching the fixed contact B, it turns the arm of the semaphore back to "line clear," the local circuit opens, and the *sonnerie* ceases to ring.

A is supposed to be at some distance, say a mile, from the crossing, while B is close by. For trains going the other way, two "fixed contacts" would be required, at C and D, but on a double track all four might be connected with one wire to the semaphore. The "fixed contacts" would, on a single-track road, have to be set, not in the centre, but at the sides of the track, so that trains going in either direction would only touch two of the four—the movable contact being also, of course, placed near the side of the engine.

If the *sonnerie* alone were used, there would be needed two batteries at the semaphore instead of one, and the direction of their poles would be reversed in order to give reverse signals on the magnet of the primary circuit before spoken of. A and C would be connected to the positive pole of one battery, and B and D to the negative pole of another. The additional cost would be trifling.

IV. Signals "Covering" the Position of Trains in Motion from Trains Following, Meeting or Crossing.

This class includes all electrical apparatus applied to the "block system," and to the system of "interlocking points" at junctions, and is perhaps the most important division of the subject of railway signals.

The term "block," as applied to railway signals, has become fixed in railway parlance, at least in England, and is used to designate a system under which the road is divided into sections, of greater or less length, protected by signals which allow only one train to be on a section at any given time. Mr. Preece thinks that the term arose from the necessity, in the earlier systems, of "blocking" or pinning over the signal-lever to protect the line from following trains. He suggests that the term "*space*" system, as opposed to that of "*time*," would probably be more accurate.

The "time" system, as employed in England, detained a train for five minutes after a preceding one had passed the signal-station, and exhibited a "caution" signal for five minutes more. Regard being had, however, to the difference in the speed of trains, and to the various accidents or delays which may happen between two signals, and which often cannot be notified to a following train in time to prevent a collision, it will be seen that the "time" system affords little or no safeguard.

The question has been very thoroughly gone into by Mr. Preece and by Colonel Tolland, Government Inspector of Railways in England. As long ago as 1862, the latter gentleman said:—

"An interval of time, as a means of avoiding collisions between trains, is, in my judgment, worse than useless; it is deceptive and thoroughly uncertain, as an interval of half an hour at one station may have entirely disappeared before the train arrives at its next appointed stopping-place; whereas, an interval of space, no matter how short, between following trains, if preserved, will always prevent a collision from taking place."

At a very recent discussion of the subject before the Society of Telegraph Engineers in London, in which both these gentlemen participated, the conclusion arrived at was almost unanimous, that the "block" system, strictly carried out, was the only certain preventive of collision. If the block is absolute, and no other is safe or entitled to the name of block, there seems to be no alternative for the use of electricity in working and maintaining it. The employment of signal-men, within sight of each other, is not to be thought of, and yet it appears to be the only way to carry out the principle of the block without electrical aid.

The only approach to an equivalent of the block in America has, until lately, been found in the system of "train despatching," but this requires, to be effective, a corps of skilled telegraphers, which cannot always be procured for railway service.

On some of the English railways, trains are run at intervals of three minutes under the block system. On the London and North-Western, the signal-stations are two miles apart, and on the Charing Cross extension of the South-Eastern Railway, less than a mile. While none of the American roads, probably, have anything like a corresponding traffic, there are many where trains run too frequently to permit of their being blocked at telegraphic stations irregularly located, and sometimes at long distances from each other. The train-despatcher's order to a following train is, therefore, to "run as section two" of the preceding one, or to "proceed, keeping a sharp look-out" for it to the next station, and "wait for orders." This at once introduces all the danger and uncertainty of the English time system.

I do not wish to disparage the manner in which the train-despatching system is conducted. Where skilled American telegraphers are employed and properly remunerated, they do their work better than any others in the world. Such men cannot be had for railway service, however, in sufficient numbers to allow a telegraph office at every point where the block system would establish a signal, and a large traffic cannot, therefore, be worked with safety by "train despatching." Were a simpler telegraph employed for the ordinary service, the block system adopted for the running of trains, and each worked by railway employés, economy and safety would, probably, both be advanced by the change.

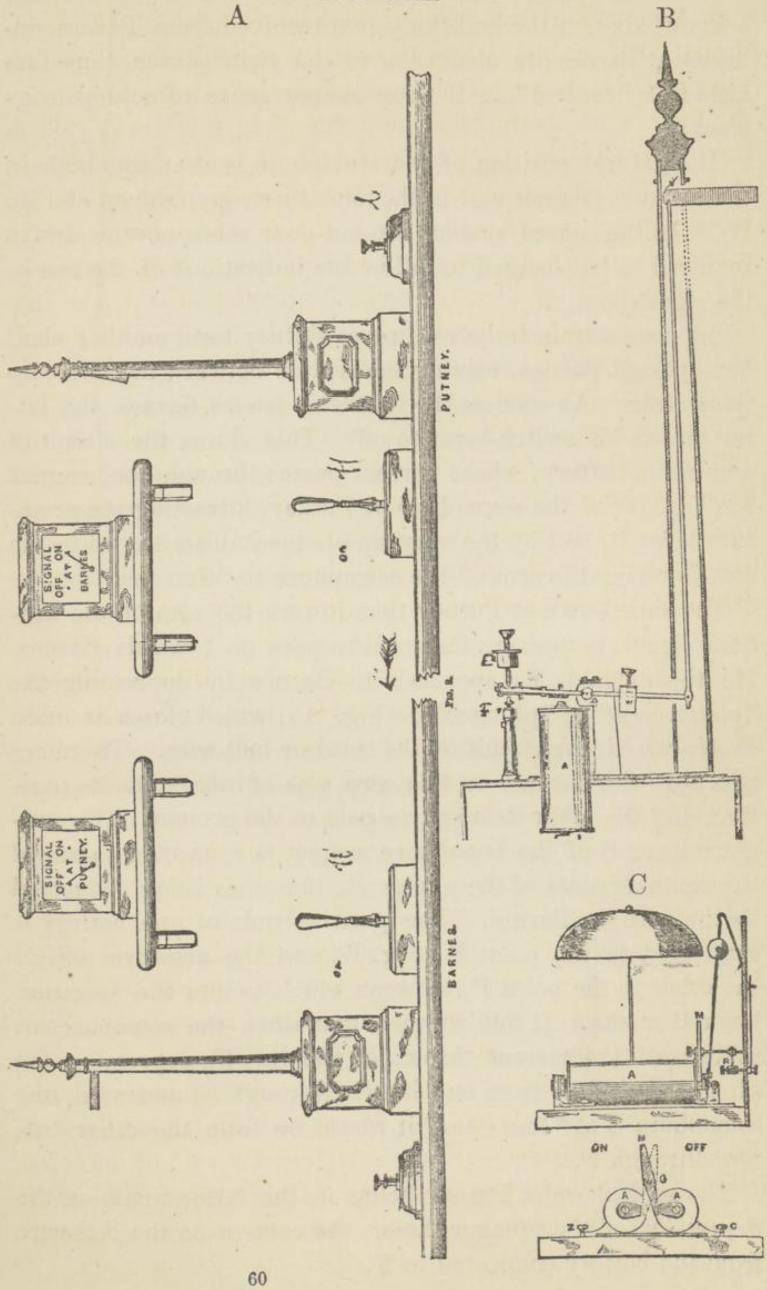
Various forms of the block are in use in England on the different railways, none of which are on exhibition at Vienna. From the simple needle to the most complicated apparatus, however, the instruments in use have merely one purpose,—that of sending a *signal* from one signal-station to the man in charge at the next, who controls the movement of the semaphore.

The system of Mr. Preece, which is adopted by the Metropolitan Railway, comprises three wires, two of which are employed for the block-signals proper, one for each line of rails, and one for movement-signals (see class 1) and acknowledgment of the block-signals. On the third wire a "bell-sounder" is employed, with a code to indicate the character of approaching trains, etc.

The apparatus is shown at Plate XIII. as working between Barnes and Putney. The semaphore and switch-lever (Fig. A) are miniature copies of those used for out-door signals worked by hand. They are inclosed in a box or placed on the counter in the signal-house at each station.

There are, according to Mr. Preece, two fundamental requirements of the system: one being that the signal-man at one station shall have "sole and complete control" of the semaphore at the other; the other being that "every signal shall be properly acknowledged, and that the acknowledgment shall not only imply the due receipt of the signal sent, but that it has been correctly understood and properly acted upon."

Plate XIII.



To fulfil these requirements, the switch-lever at Barnes must "control" (in the sense of change) the position of the semaphore at Putney, and the semaphore at Putney must, with the aid of the Putney signal-man, whose business it is to acknowledge on the bell the signal received from Barnes, indicate at Barnes its obedience to the switch-lever, thus furnishing a "control" in the continental sense of acknowledgment.

The natural position of the semaphore is at arrest, both in the out-door signals and in the miniature copy (shown at Fig. B). In the signal system the out-door semaphore is always required to be changed to follow the indications of the one in the signal-box.

Suppose a train to be waiting at Putney until another shall have passed Barnes, leaving the section between the two stations clear. As soon as the first train passes Barnes, the latter throws his switch-lever to off. This closes the circuit of a galvanic battery, whose current passes through the magnet A (Fig. B) of the semaphore at Putney, attracting the armature lever B, and by the very simple mechanism shown in the cut, lowering the arm of the semaphore to "line clear."

The signal-man at Putney then lowers the arm of the out-door signal, permitting the train to pass on towards Barnes. He then signals its approach to Barnes by depressing the "piston-key" or "plunger" *b* (Fig. A), which closes as often as depressed, the circuit of the third or bell-wire. There are two batteries for use on this wire, one of which has its positive, and the other its negative pole to the ground. The armature lever B of the semaphore magnet is connected to one of the contact points of the plunger *b*, the other being connected to the wire to Barnes. The positive pole of one battery is connected to the point E (Fig. B) and the negative pole of the other to the point F, between which points the armature lever B works. It follows then that when the semaphore is at "arrest" the current thrown on the line by depressing the plunger would be from one battery through E, and when the semaphore is at "line clear" it would be from the other battery through F.

The semaphore at Putney being in the latter position, the depression of the plunger throws the current on the bell-wire from the battery connected to F.

This current first actuates a bell-sounder at Barnes (Fig. C) in the ordinary manner, announcing the approaching of the train from Putney. In addition to the ordinary hammer-armature, however, there is a permanent magnet M swinging between the poles of the electro-magnet, as shown in Fig. D. When the battery from E is on the line, this magnet swings over to the left, and when the battery from F is on, it is then thrown to the right, in consequence of the different polarities given to the electro-magnet by the change of the direction of the current. The axis of this permanent magnet is prolonged as in the Italian switch-control heretofore described (see Plate V.), and works a rack and pinion movement, shown in the cut, which controls a needle-indicator on the outside of the case. The movement of the indicator is, of course, the reverse of that of the magnet. (Fig. A.)

The permanent magnet at Barnes once thrown to "off" by the signal-man at Putney, is not again disturbed except by a reversed current from the battery through E, which cannot be put on the wire while the semaphore at Putney indicates "line clear." Any number of signals may, therefore, be made on the bell at Barnes indicating the character, etc., of the approaching train.

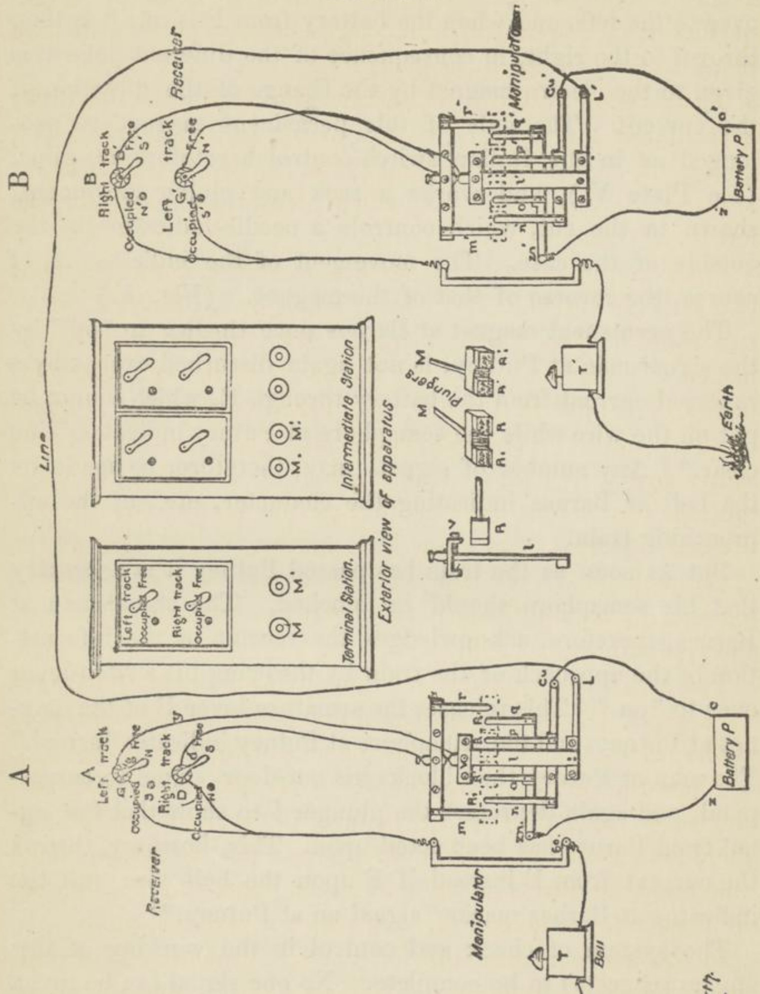
But as soon as the train has passed Putney it is necessary that his semaphore should be blocked. The signal-man at Barnes, therefore, acknowledges the receipt of the information of the approach of the train by throwing his switch-lever over to "on." This releases the armature lever B of the magnet at Putney, and the semaphore at Putney indicates "arrest." The man at Putney then blocks his out-door signal to correspond, and again depresses the plunger *b* to show that the signal from Barnes has been acted upon. This, however, throws the current from E instead of F upon the bell-wire, and the indicator at Barnes marks "signal on at Putney."

The system of check and control in the working of this apparatus seems to be complete. No one signal can be given and acknowledged without the concurrence of the signal-men at both stations, and the chance of accident through its fault is reduced to a *minimum*.

The system Tyer is in use on several of the English railways, and on the Lyons and Eastern railways in France, and is highly spoken of by the managers as well as by M. Amiot, the French inspector of telegraphs, in his report to which I have alluded.

Plate XIV. illustrates its general appearance and working.

PLATE XIV.



At the terminal station A, the "receiver" consists of two coils of electro-magnets, G and D, both communicating on the one hand with the ground through the medium of a "trembling-sounder" T, and on the other hand with the manipulator, to be hereafter described. Each of these coils is placed above the centre of a permanent horseshoe magnet, whose poles N, S, touch lightly the exterior surface of the platina, under the indications "occupied," "free," and contains a core of soft iron, at the upper extremity of which a light needle, d, g, also of soft iron, vibrates freely between the two poles of the permanent magnet.

The receiver at the intermediate station B does not differ from that of the terminal station except in that the coil D^1, giving the signals for the right track (in going from B to A) is placed above the coil G^1, which gives the signals for the left line of rails.

The manipulator is the same at both stations. It comprises two buttons, M and M^1, which, when pressed down, move two rods, held by spiral springs. Each of these rods is furnished at its farther extremity with two insulated rectangular pieces of copper R, R_1, R^1, R^1_1, placed in front of a series of seven upright metallic springs, m, n, o, l, p, q, r. The centre spring l, connected at the bottom with the line wire, touches at the top, when neither of the buttons M, M^1, are pressed down, upon a screw V, connected to the wire of the "left track" coil G. The six other springs are connected together by metallic bands, two by two, as shown in the cut, and communicate as follows: —

The two inside springs m, r, with the wire of the "right track" coil, D, the two springs *n* and *p* with the copper pole of the battery, and the springs *o* and *q* with the zinc pole.

When the right-hand button M^1 is pressed, the copper rectangles at the end of its rod connect the springs *l* and *p*, and *q* and *r* as shown in the dotted lines of the cut, at the same time breaking the connection between *l* and v and insulating the former from the coil G, with which it communicated.

In the same manner the left-hand button M, if pressed, would insulate *l* from G, and connect *l* with *o*, and *n* with *m*. The effect of this would be, as will be easily seen by tracing the connections, that when the button M^1 is pressed, a positive current will be transmitted on the line L and a negative current through the coil D and the *sonnerie* T. In pressing the button M, exactly the opposite effect will be produced.

Supposing N and S to represent the north and south poles of the permanent magnet, it will be easily seen that on the pressure of the right-hand button M^1 at the sending station, the negative current sent through the coil D would develop a north pole at the near extremity of the soft iron core of that helix, which polarity would be communicated to the free end of the needle *d*. This needle, attracted by the south pole S, and repelled by the pole N of the permanent magnet, would be thrown over to the indication "free," while the positive current sent over the line through L, thence through L^1, l^1, to the coil G^1, at the receiving station, would develop a south pole at the free end of the needle g^1, which would be thrown over to N^1, *i, e*, to the indication "free," as at the sending station.

The pressure of the left-hand button M would, by reversing the direction of the currents, have a contrary effect on both the needles *g* and d^1, indicating "occupied." The same effects would be produced by pressing M, and M_1^1, at the other station upon the needles d^1 and *g*.

Each signal sent from either station sounds the bells T and T^1, calling attention to the signal.

Suppose a train now to leave the station A for B, no other being on the line between the two and all the needles being therefore at "line free." The agent at A having covered the train by his out-door signal, presses the button M^1. The needles *d* and g^1 being already at "free," this would simply ring the bells of the two stations without changing the indicators.

The agent at B, thus advised of the coming of a train, acknowledges the signal by pressing his left-hand button M_1. He also rings the *sonneries* T^1 and T, at the same time throwing over the needles d^1 and g^1 to "occupied." The needles at both stations thus indicate that one line of rails is occupied, and that at A is a reminder that the outside semaphore should be at "arrest."

When the train arrives at B, the agent there presses the button M_1^1 and brings back to "free" the two needles d^1 and *g*, again ringing the bell T to notify A of the arrival of the train.

If when one train is coming from B to A, another passes A on the second track for B, the agent at A, instead of pressing M^1 to advise B of its departure, which would throw the needles d and g^1 to "free," presses the button M, *towards which the needle d is now inclined as in the case before described it was inclined towards* M^1.

It is not necessary to repeat the rules adopted for the entire system of signalling, which are the same as in any "block" system. To carry them into effect on the apparatus, the following special directions are given:

1. To signal the *departure* of a train, press upon the button towards which is inclined the needle of the "right track."
2. To acknowledge this signal, press upon the button under the indication "occupied."
3. To announce the *arrival* of a train, press upon the button under the indication "free."

The two instruments necessary for intermediary stations are generally inclosed in one box, as shown in the cut.

The system of Mr. Tyer, in a telegraphic point of view, is very ingenious and possesses the great advantage of requiring but one wire. Like Mr. Preece's system, each signal requires the concurrence of the agents at both stations before it is completed. There is, therefore, very little danger from atmospheric electricity. Unlike Mr. Preece's system, that of Mr. Tyer does not give the man at one station "sole and complete control" of the indicator at the other. But the control spoken of by Mr. Preece is only electrical, and might easily be overcome by mechanical means. It being suggested that the signal-man might "tie down the arm of the semaphore with a string," Mr. Preece very aptly replied that he might also "neglect his duty, disregard his signals, and swear that the semaphore was down when it was really up."

In the Tyer system a signal-man to change his own signal must also change that of his neighbor, and this is probably as good a control as putting it out of his power to interfere electrically with his own indicator.

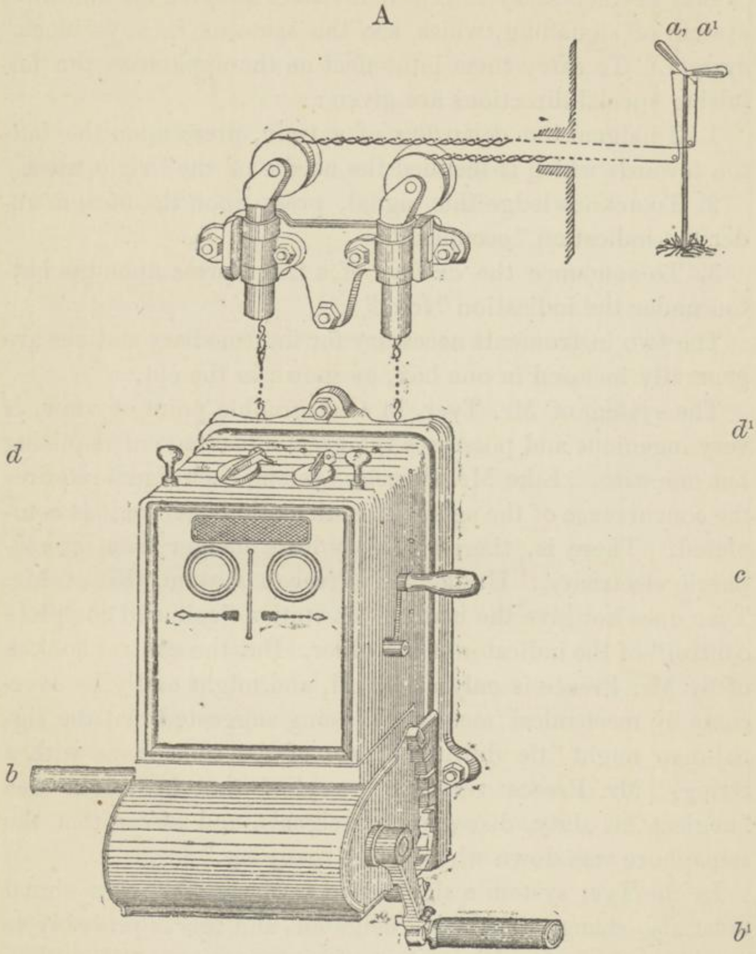
The new system of Messrs. Siemens & Halske, exhibited both in the German and English departments at Vienna, goes a step farther towards the control of the signal-man than either the Preece or Tyer system. By the kindness of Dr.

Werner Siemens, of Berlin, I have been furnished with drawings of this apparatus which are here presented.

A shows the external appearance of the apparatus at an intermediate station, the arms a, a^1 of the semaphore being

Plate XV.

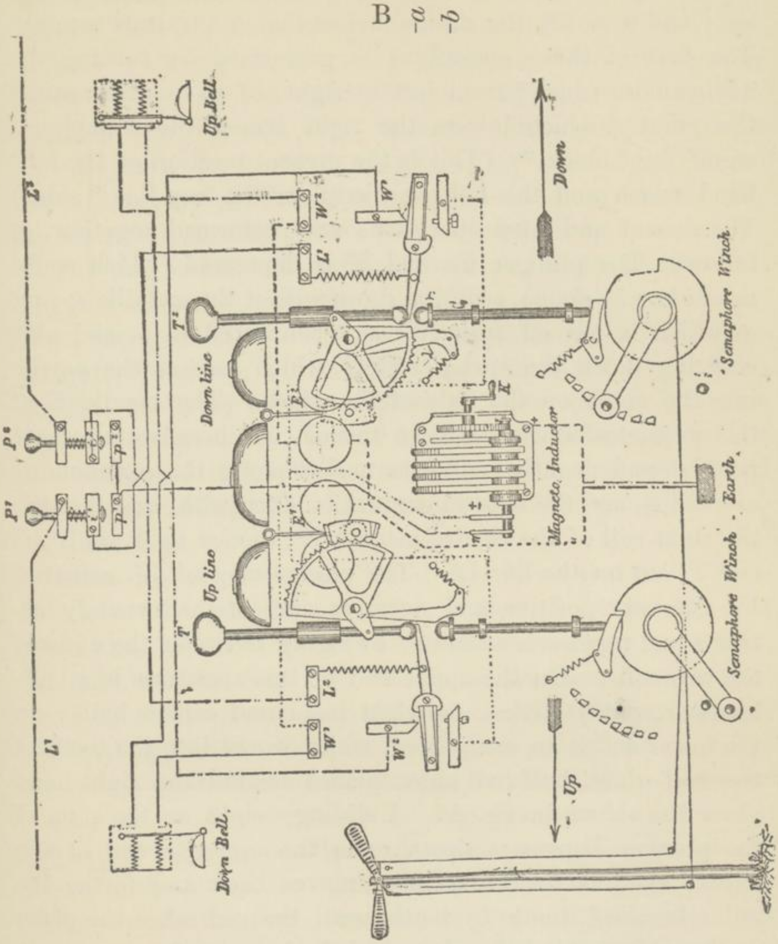
A



worked by the cranks b, b^1. The arm a gives the signal for up, and the arm a^1 for down-trains. The crank c is used to turn a magneto-electric apparatus in the box, from which currents are transmitted in one direction or another, accordingly as the commutator knob or plunger d or d^1 is pressed down. The discs shown on the face are controlled by the current, and show white or red as the line is clear or blocked on their respective sides. B shows the internal mechanism and connec-

PLATE XV.

B



tions, with the addition of duplicate sets of bells and plungers (P^1 and P^2), not shown in A, which are used for signalling the forward movement of trains. There are other forms of the apparatus, but this is the most complete, and was the one chosen for exhibition at Vienna.

The figure shows the up-track "blocked" and the down-track clear. A "down" train, we will suppose, is about passing the station. The signal-man has four things to do:

to set his out-door signal at block, so as to prevent a second train passing down; to set the disc in his box to correspond with the semaphore; to notify the station above him that the train has passed, in order that the latter may unblock his signal; and to notify the station below that the train is coming. The first of these operations is performed by turning the "semaphore winch" from left to right, so as to rest against the point *f*, which lowers the right arm of the semaphore, signifying "block." (This is the present position of the left-hand winch and the left-hand arm on the "up-line" side.) The second and third operations are performed together, as follows: The plunger marked T^2 is depressed (which could not before be done), carrying down with it the metallic spring *a*, which is cut off from W^1 and connected to *b*, and also carrying down the spring rod G, which presses the pawl *c* into the notch on the axis of the winch. The handle K of the magneto-inductor is then turned, which causes alternate positive and negative currents to flow along the commutator marked + and the wire in connection therewith, and through the right coil of the electro-magnet E^2, thence by *b*, *a*, L^1, i^1 and P^1 out on the line L^1. The electro-magnet E^2, actuated by alternate positive and negative currents, alternately attracts and repels an armature swinging between the ends of the two coils. On the upper end of this armature is a bell-hammer, which strikes the right hand and centre bells; on the lower end is an escapement which works into the teeth of the half-white, half-red index placed behind the right hand glass disc shown in fig. A. A sliding weight on the stem of the plunger T^2 presses down upon the opposite end of the index, and, as the escapement moves back and forth, the index is raised, tooth by tooth, until the red takes the place of the white behind the glass, and the box-signal corresponds with the semaphore. The depression of G has allowed a lever *l* to press against the shoulder H on the rod, and, as the index rises, its axis, half of which is cut out, prevents the lever *l* from returning. The rod G, therefore, holds down the pawl *c*, *and prevents the out-door semaphore from being unblocked until the index is brought back to white, or "line clear.*" This will be understood by reference to the left side of the diagram.

Now, whenever the plunger T^2 is depressed, the sliding-weight on its rod presses on the tail of the index and prevents its descending, the index can only be brought down again and the semaphore released by a current from the station below when T^2 is up. This brings us to the third operation performed by the signal-man, which is to notify the station above, by unblocking his box-signal and releasing his semaphore, that the train has passed. The "up-line" side being blocked on the diagram, the method of unblocking will appear if we trace the course of the circuit on that side from wire L^1, P^1, i^1, L^1, a, W^1, through "down-bell" W^1 and the right coil of the electro-magnet E^1 to the ground. The alternate positive and negative currents move the escapement on the lower end of the armature, and the index, not being pressed by the sliding-weight, which would give it an upward bias, falls, by its own weight, tooth by tooth. White, or "line clear," is shown behind the glass; the lever l is released by the half-turn of the axis, and this releases, as well, the spring rod G and pawl c, permitting the signal-man to turn his semaphore also to "line clear."

From the above explanation it is evident that the signal-man cannot advise the preceding station of the passage of a train until he has first blocked his own semaphore; and that, having once blocked his semaphore, he cannot unblock it until he has received clear and unmistakable notice from the succeeding station that the train has passed there. Two motions—depression of the plunger and turning the handle of the inductor—are necessary for any signal, and, as a succession of alternately positive and negative currents is required to move the index, no signal can be delivered by lightning or other accident. For convenience, one coil (or rather one magnet; for the two coils are not connected as in ordinary electro-magnets) is used on each side for arriving, and the other for departing, signals.

To signal the forward movement of trains from one station to the next, the upper plunger, say P^2, is depressed and the handle of the magneto-inductor turned. The current then goes from the commutator marked T to P^1, P^2, and i^2, where it divides, a portion going out on the line, and the rest through L^2, W^2, up bell, and the left coil of E^2 to the ground.

But half of the spindle, where touched by T, is cut away; hence, only one current is transmitted, and, as the armature of E^2 requires alternate positive and negative currents to attract and repel it, rocking the escapement, the index is not moved either at the transmitting or the receiving station. The only effect, therefore, of turning the crank when the upper plungers are depressed is to ring the bell at the station above or below, as the case may be, thus advising the signal-man of the approach of a train.

As far as safety is concerned, the apparatus of Messrs. Siemens seems to fulfil the requirements of a block-system more completely than any other yet introduced in Europe. No accidental signals can be given, and neglect of duty on the part of the signal-man causes no danger, but only delay. Danger may arise, as in any of the systems yet described, from the train breaking in two without the knowledge of the engineer or of the signal-man, who, on its passage, would unblock the signal of the preceding station while cars might be standing on the track between the two. There is also the chance, always remote, that the signal-man will wilfully do wrong, and, his own block being on, signal to the preceding station that the train has passed, when, in fact, it has not. The adoption of induction instead of galvanic currents, the control by one signal-man over the semaphore of another, and the use of but one wire, give this system an advantage over the preceding block instruments. It has, however, in common with them, the disadvantage of being quite expensive, and requiring the constant attention of a signal-man at each station.

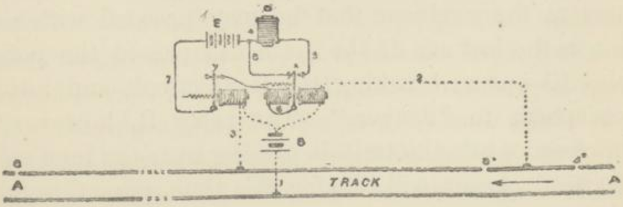
These last two considerations would probably alone be sufficient to prevent the adoption of this or indeed any of the block systems yet described, on American railways.

Within the past five or six years, the automatic signal of Mr. Hall, before described, has been, by a slight change in the relative position of the semaphores and circuit-closers, made to serve as a block system. The semaphores, enclosed in suitable cases, are placed at intervals of about a mile along the track. Thus, when a train passes one of the signal-stations, the wheels of the locomotive will depress a lever, close an electric circuit, and display a danger-signal, which is provided with a detent, serving to retain it in this position after the train has passed. When the train arrives at the next signal, this operation is repeated, and at the same time a second circuit is closed, running back to the first-mentioned signal, and releasing or reversing it. Thus each train is supposed to maintain a danger-signal at least a mile in the rear at all times.

Although this system dispenses with the expense of attendants, it still requires two wires, the lever is liable to be displaced by the shock of passing trains, and the failure of a wire or battery may cause a failure to display the danger-signal at a critical moment. Like previous systems, it does not provide for the breakage of a train, and it is not adapted, without considerable modification, to a single track railroad, it being what is called a "non-following," but not a "non-meeting" block. The system which seems to obviate these objections the most completely, has been produced by Mr. F. L. Pope, of the Electric Railroad Company of New York.

Mr. Pope's system is based on the electrical law, that a current will divide itself between two conductors, in proportion to their respective conducting capacity, and by numerous carefully conducted experiments, he found that the conductivity of a mile or more of ordinary fish-jointed rail exceeds that of the cross-ties and ballast between the tracks, even in very wet weather. Bearing this fact in mind, it will be easy to understand the system.

PLATE XVI.



In Plate XVI., A A represents a railway track. One rail forms a continuous conductor, while the other is divided, electrically speaking, into sections, by means of insulated joints a a^1 a^2. The long sections a a^1 are a mile or more in length, while the alternating short sections a^1 a^2 are only about fifty feet in length. The trains are supposed to move in the direction indicated by the arrow. The electric magnet S which operates the semaphore, together with the semaphore itself and its fixtures, are placed 200 or 300 feet in advance of the short section a^1 a^2. The semaphore is the same shown in Plate XI., under class 2.

Opposite the signal apparatus, a battery B is connected to the continuous rail of the track by a wire, 1. From the opposite pole of the battery, two wires, 2 and 3, are conducted to two relays, R and R^1, and thence to the long and short sections of the other rail, a a^1 and a^1 a^2 respectively. These two relays control the local circuit 4, 5, 6, 7, which operates the semaphore, by means of the local battery E.

The normal position of the semaphore indicates "danger." But whenever a current is passing through the magnet S, it will indicate "safety," until the current is interrupted, when a counterbalance weight returns the signal to its former position.

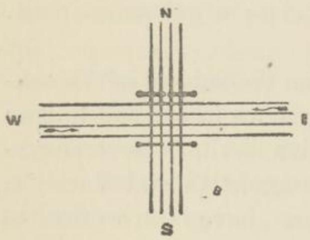
When a train, passing in the direction of the arrow, reaches the short section of rail, its wheels and axles form an electrical connection with the opposite rail, closing the circuit of the relay R^1, the armature of which in turn closes the local circuit at x. A moment afterward, the advancing train reaches the long section at a^1, actuating the other relay R in the same manner, and closing the local circuit at y. The local circuit being now complete at x and y, the electro-magnet S is charged, and a safety-signal shown, which indicates to the engineer that he may proceed with safety. As soon as the last car of the train has passed the point a^1, the relay R^1 opens, breaking the local circuit and returning the semaphore to "danger." The relay R, however, will remain closed while the train is passing over the long section, and the local circuit will, during this time, pass through the wires 6, 7 and 8, including the retaining magnet M. If, therefore, another train should enter upon the short section a^1 a^2, it would be unable to close the local circuit at x, and thus cause a safety-signal to be shown, because the armature of the relay R^1 would be held fast by the attraction of M.

In this system it will be seen that the circuit closers, being composed of sections of the track itself, are not subject to wear or derangement; a safety-signal cannot be shown unless every battery is in working order, and every wire unbroken; nor can a safety-signal be given when any part of a preceding or meeting train remains upon the section of track between two signal-stations.

Experiments have been made on a prominent American railway with an apparatus for block and other signalling, the invention of a Mr. Rousseau, based on the well-known principle of the deflection of the magnetic needle by the proximity of a mass of iron. An ordinary compass needle is placed on a post at the side of the track, and on the passage of the locomotive it is deflected, so as to close a galvanic circuit, by which a semaphore is operated.

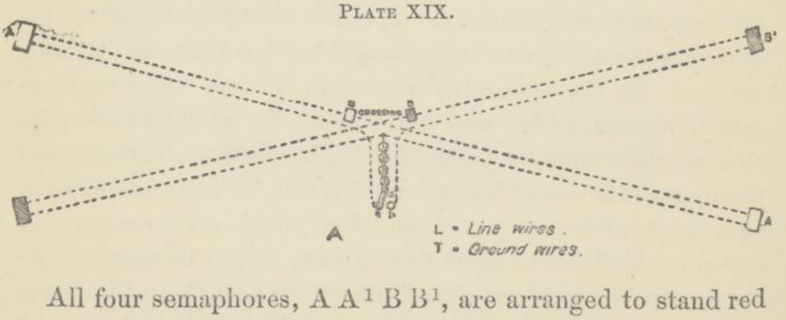
Enough has been said, probably, on the subject of "block-signals," to illustrate the different systems in use and to give the reader an idea of their comparative merits. Several systems, such as Clark's, Walker's, Spangoletti's and Varley's, requiring the services of a signal-man, have been worked in England more or less satisfactorily. Of two new automatic English systems, Carr's and Binney's, I have been unable to secure descriptions. The latter, however, seems to resemble, in some respects, the system of Mr. Pope. The points of an American system, Robinson's, are covered it is claimed, by Hall's and Pope's instruments.

When the block is worked at junctions, it is known in England as the system of "interlocking points." The best known, perhaps, of these systems, is that of Messrs. Saxby & Farmer, the invention of an employé of the North London Railway, named Chambers. It is not electrical in its operation, but the objects to be accomplished are the same in every system. In the apparatus shown at Vienna there are two sets of signals, called near and distant, for each line of rails, making eight signals at a double-track crossing. The normal position of the semaphores is at "arrest." They are worked by a range of levers at the junction, which are so connected that no one of them can be moved so as to put its corresponding semaphore at "line clear," unless the signals on the crossing tracks are at "arrest." The levers and semaphores are numbered, and on each lever are also painted the numbers of the levers and semaphores, which must be at "arrest" before it can be moved. Hence, if the engineers obey the signals, there is no danger of collision. Delay, and not danger, is produced by the neglect of the man in charge of the levers. Where there are switches, as in the case of a branch line, each switch is connected to the same lever as its semaphore, and the signal cannot be put at "line clear" unless the switch is right. In the model shown at Vienna, there are also gates which close across one line of rails, as for instance, those running north and south, when trains are crossing east and west, and *vice versa*.



In electrical interlocking systems, the "circuit" on which each semaphore is placed, is carried through the "points" of the other semaphores or switches, which must be closed in order that the first semaphore may be worked. Messrs. Siemens & Halske, have an elaborate apparatus on exhibition at Vienna, in which each switch and its corresponding semaphore is connected to a sliding-bar and a lever at the junction station. By means of the electrical apparatus used in Siemens' block-signals, no switch or semaphore can be moved until all the switches and semaphores on crossing tracks are placed at "arrest." Mr. Pope's electrical semaphore has been adapted to the interlocking system, the connections being made in the following manner:—

PLATE XIX.



All four semaphores, A A[1] B B[1], are arranged to stand red by the action of gravity, when no current is passing. The switch S being turned on the point *a*, gives the right of way on the semaphores A and A^1. Turning it to *b* would reverse the arrangement. It is obvious that the battery can only be on one pair of signals at a time, and that a white signal on one road necessarily involves a red one on the other. By placing S between the studs *a* and *b*, all the signals may be kept at red, except when a train on either road is to be passed over.

5. Signals Between the Various Portions of a Train.

The signals embraced under this head are so few and comparatively so unimportant, that, but for the distinctiveness of their object, they would scarcely be entitled to separate classification. In Europe, where the cars are divided into compartments and the passengers locked therein, a necessity may sometimes arise for immediate communication between the passenger and the guard or conductor; but even in such cases the ordinary American bell-rope would seem to be as certain and convenient as the electrical and pneumatic apparatus in use on some European roads. I have seen at the Exposition an elaborate piece of mechanism, worked by compressed air, by means of which a passenger in danger was enabled to ring a bell in the conductor's car, and to light a lamp at the door of his own compartment at the same time, so that the conductor might know exactly where his assistance was needed. It does not seem probable, however, that such an apparatus could ever be required on American railroads. To warn the conductor or engineer of the breaking of a train the bell-rope would also seem sufficient; or, if not, an arrangement similar to that used by Mr. Pope in his block-signalling system would obviate all danger.

Electric brakes have from time to time been invented, but, so far as I know, never applied with anything like the success which has attended the operation of the air-brake system. One of these, the invention of M. Achard, is on exhibition at Vienna. Frequent experiments have been made with it on various French railways, but none have been altogether successful. Neither the brakes, however, nor the various contrivances for electrical gas-lighting, etc., on trains, properly come within the scope of this report.

6. Signals to be Used in Case of Accident.

The sixth of the classes into which I have divided railway signals is also small, and contains little which has not already been alluded to under another head. Only one apparatus constructed solely and specially for a "distress-signal" is on exhibition at Vienna.

On some of the French roads, a Morse or other speaking telegraph is carried on each train, to be attached to the line in case of accident. On others, as that of the *Compagnie du Nord*, a dial telegraph is placed at intervals of about two and one-half miles. The number of these on the lines of that company, is between two and three hundred. They are arranged like the Siemens signal, described in class 1, so that shutting the door of the signal-box, closes the circuit automatically.

Messrs. Siemens & Halske have in their case, at the Exposition, an apparatus consisting of an upright iron standard, surmounted by a signal-box, in which is placed appropriate clock-work. These boxes are placed at short intervals along the road, and on each train is carried a set of keys of different length, corresponding in number to the number of signals embraced in the code. Each key, therefore, has its corresponding signal in a code, similiar to that used in the system of Mantelli (Plate II). In case of an accident, the signal desired is produced by inserting the proper key in an aperture in the signal-box. The clock-work is released, and an electric circuit is automatically closed and opened a certain number of times, according to the length of the key. Whenever the circuit is closed, a bell is rung at the box, and another at the station from which assistance is expected. At the latter, the closing of the circuit also automatically releases a series of clock-work, carrying a strip of paper, as in the ordinary Morse register, on which paper the code signal is printed.

Where accidents result from, or lead to, the displacements of rails, it would seem possible (by an application of the principle of Mr. Pope's block-signal), in the one case, to prevent them by advising a coming train of the displacement, or in the other, to notify, by electric and automatic means, a station from which assistance may be obtained.

ROBERT B. LINES.