DIVISION III.

MISCELLANEOUS APPLIANCES.

CHAPTER XVI.

SIGNAL REPEATERS.

188. Of the numerous applications of electricity to railway working, none are more worthy of attention than that by which the position of the signals which regulate the traffic is repeated back to the point from which they are worked.

If it is necessary to employ signals at all, it is equally necessary that they should work as they are intended—that is, that when they are, by the lever working them, placed at *danger*, they shall really stand at *danger;* and when they are "pulled off" they shall, in like manner, stand at the "clear," or "caution" position, according to the requirements of the locality, or the arrangement of the signal. Even with very careful attention on the part of those working them this cannot always be insured. The slightest change in the temperature, a passing cloud on a warm day, will lengthen or shorten the wire by which

the signal is worked. During night the wire will become contracted, and under the warmer atmosphere of the day it will again expand. These changes are constantly going on, in a greater or less degree, both night and day,

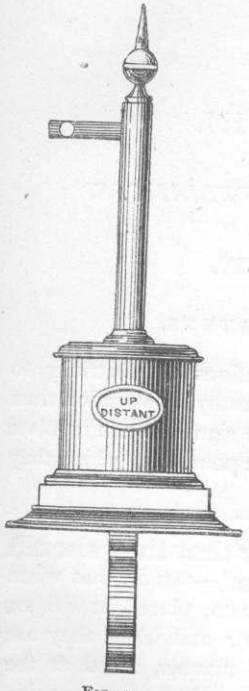

FIG. 97.

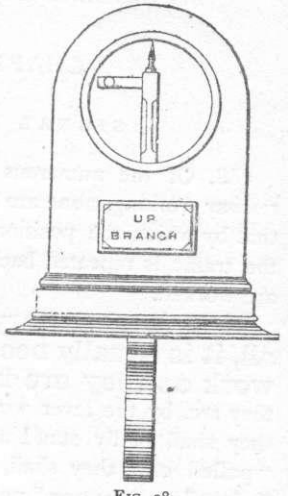

FIG. 98.

and to obtain a faithful action of the signal, the wire by which it is operated must be let out, or taken in, to meet these variations. If, in order that the signal may not fail to *go on*, the wire is allowed a superfluity of

slack, the arm cannot be lowered to its proper degree to represent the "all clear," or "caution" signal, and this induces carelessness and indifference with drivers. If the wire, on the other hand, is too tight the signal cannot assume the "danger" position, in which case the danger is enhanced.

So long as a signal is within a man's sight he may, in the majority of cases, be held responsible for its due action; but this is not possible at all times. Fogs and storms will arise, snow will cloud his view, and buildings, trees, or the construction of the line, place the signal out of sight. Even when it is within his view other duties may form an excuse for not keeping so careful an eye on it as is to be desired; but if an instrument is placed before him which tells him whether the signal is *on* or *not*, or whether it is *on* or *off*, and it is a part of his duty when working the signal, to learn by this instrument whether the signal *has responded to his action*, the responsibility becomes too great to be ignored.

At night time, and during foggy weather, all depends upon the light within the signal-lamp and the due action of the "spectacles." If the light goes out there is no signal. If the spectacles fail the signal is false.

Electricity affords a means for ascertaining the position of the arm to a fraction of an inch; and by its means we may also assure ourselves of the due action of the "spectacles," and of the existence, or non-existence, of the light.

Figs. 97 and 98 are outside representations of an arm, and Fig. 99 is a representation of a combined arm and light repeater.

These instruments may be made of any form. Those represented in the figures are known as Preece's and are made of various shapes, sometimes as represented, at

others in a small rectangular case, and again in a circular case, according to the position they are required to

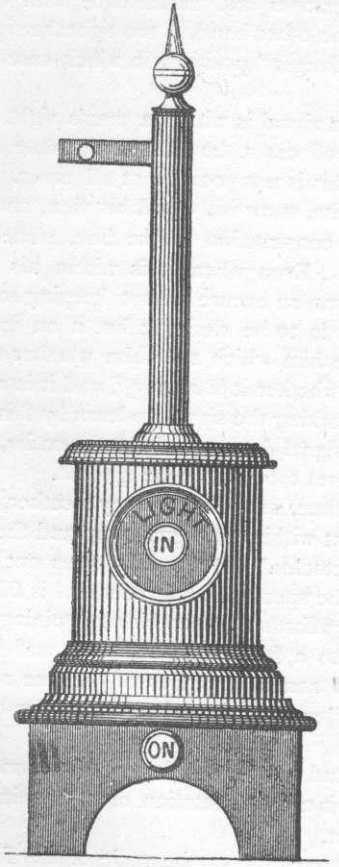

FIG. 99.

occupy and the taste of the telegraph engineer Mr.

W. H. Preece was the first to employ them, about the year 1861. Mr. A. Warwick, of the Midland railway, shortly afterwards introduced them on that line, and they are now very generally employed on all important railways. The form of indicator (Fig. 100) adopted by Mr. Warwick is that of a needle, which, for the arm, is made to point to "signal on" or "signal off" as the case may be; whilst that referring to the light is directed in a similar manner to "light in" or "light out."

189. Each indicator—that for the arm or that for the light—requires an insulated wire between the signal-post and the instrument.

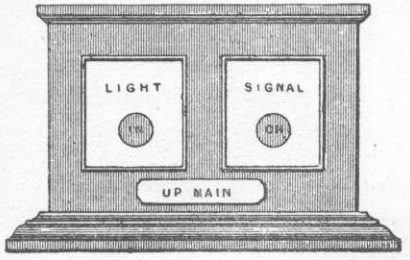

FIG. 100.

To one end of the coils from which the arm is worked is attached a battery A (Fig. 101), the other pole of which is to the earth, and to the other end of the coils is connected the line wire B, which is continued to the signal-post, and there attached to the spring C of the contact maker (Fig. 102) fixed in close proximity to the signal arm. To the back of this arm is a metal stud D, the object of which is, when the arm is at danger, to press against the spring C and so bring it into contact with the point E, which is in connection with the *earth*.

Now, when the arm is raised to danger, it will bring D in contact with C, which will be pressed against E, thereby completing the electrical circuit between earth at the signal-box, and earth at the signal-post. The

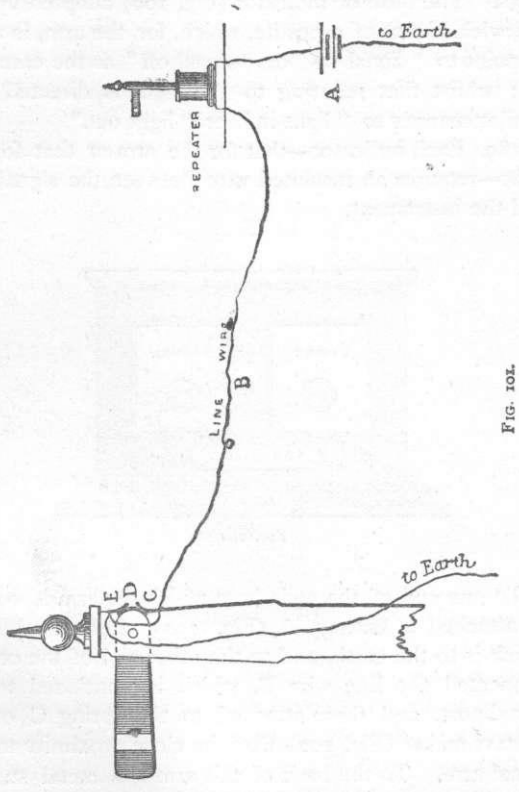

FIG. 101.

battery current will then flow from A, through the coils of the instrument, raising the arm to danger, along the line wire B, to C, and thence to E and the "earth."

On the signal arm being in the least depressed, C will cease to press against E, and the connection between the line wire and the earth being thus interrupted, the current from A will cease to flow. The coils of the instrument,

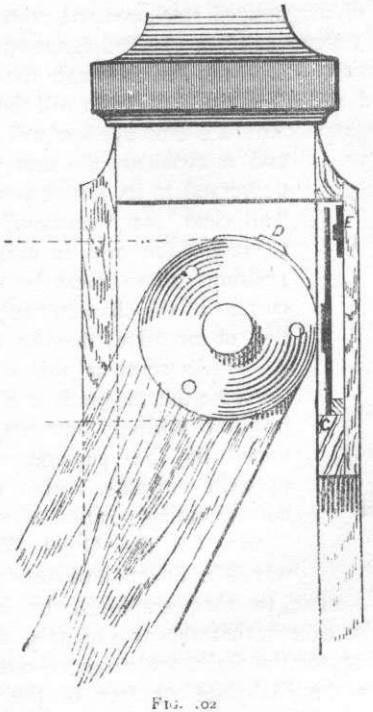

FIG. 102

now no longer excited, will exercise no influence over the armature by which the arm of the repeater is actuated, and the arm will fall to its normal position, indicating that the signal arm is *not on*.

190. Fig. 103 represents an arrangement for obtaining a record of the condition of the signal arm at three different positions, viz., when it is at *danger;* when it is at *all clear*, or *caution;* and when it is in a position *between* either of these signals. E F is the electro-magnet, *n n'* two pieces of magnetized steel, centred at *a*, to which is connected, eccentrically, a wire rod *b*, actuating the arm. When a positive current is sent through the coils, *n* will be attracted and *n'* repelled; the arm will thus be raised. When a negative current is employed, *n'* will be attracted and *n* repelled; the arm will then be depressed to its lowest position, either "all clear" or "caution." In order to retain the arm in either of these positions there must be a constant current of the character required (positive or negative) flowing through the coils. As soon as this ceases to be the case the magnets, *n n'*, assume a position midway between that produced by the passage of the two opposite currents, which produces a corresponding position of the arm.

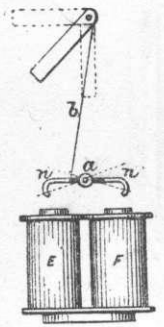

FIG. 103.

191. On the Great Western railway Mr. Spagnoletti uses a form of instrument similar to that employed by him for his block-signals, except that the two signals, that for the arm and that for the light, are arranged one above the other. On the dial-plate or face of the instrument is painted the word "Signal," immediately over the aperture which is filled by the shield (Fig. 60) carrying the words ON and OFF; either one of which should be exhibited at the aperture according to the position of the arm or the signal which it repeats; when this is not the case the shield assumes a neutral position, showing a portion only of each word.

192. Repeaters, giving more than two indications, require additional wires, or that the batteries should be kept at the signal-post. The employment of a reversing key at the arm would dispense with one battery; but inasmuch as this would subject the battery employed to constant use, any advantage attending such an arrangement is questionable.

193. An ingenious method has been proposed by Mr. W. H. Preece, by which this difficulty may be overcome. He suggests a duplex arrangement such as is shown in Fig. 104.

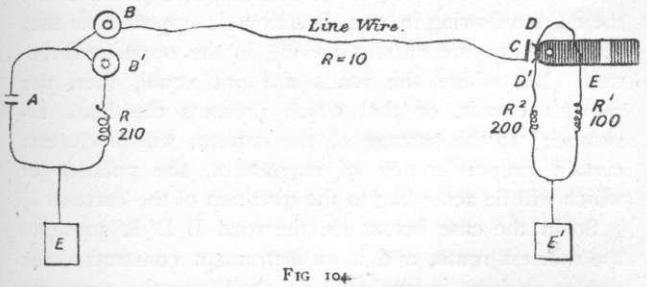

FIG 104.

A is the battery, B B' the coils of the repeater, R a small resistance measuring 210 ohms, C the spring in connection with the signal-post, D a stud on the arm, making contact with the spring only when the arm is raised to the danger position, D' another stud, also on the arm, making contact when the arm is in the position representing "caution." In connection with D is a small resistance coil R' of 100 ohms, and in connection with D' is another resistance coil R^2 of 200 ohms, both of which are joined to "earth."

Now when the signal-arm is raised so as to place C in contact with D, the battery current will have two roads open to it—one *viâ* B, D, and R′ to earth at the signal-post; the other *viâ* B′ and R to earth at the signal-box; but as the resistance of the one circuit, or road, is double that of the other, the influence of the current will be twice as great on the one coil as it will on the other. And if the coils of the instrument are connected up in such a manner that any current passed through them shall produce magnetism of an opposite character in the cores, it will be evident that when the two roads are equal, and consequently a current of equal force passes through each coil, no magnetism whatever will be engendered, for the reason that that produced by the current flowing in one direction, is opposed to that produced by the current flowing in the opposite direction. But where the roads are not equal, then the shortest circuit, or that which presents the least resistance[1] to the passage of the current, will produce a certain preponderancy of magnetism, the polarity of which will be according to the direction of the current.

So in the case before us, the road B D R′ presents the shortest route, and if an instrument constructed for duplex working is employed we shall have the armature attracted by one coil and repelled by the other; producing the "danger" signal.

If the signal-arm is lowered to the "caution" position, we shall have the stud D′ in circuit with the spring C,

[1] *Resistance* implies that quality of a conductor in virtue of which it prevents more than a certain amount of work being done in a given time by a given electro-motive force. Thus the space between any two points offers a certain obstruction to the passage of the current, no matter of what the space be composed, whether air, water, metal, or other material. The obstruction offered to the current is termed resistance.

and now the two roads will be equal; the battery current will divide on entering the coils. One portion will pass through coils B, line wire (R = 10), D′, $R^2 = 200$, to earth at the signal-post. The other portion will take the artificial route by way of coils B′, R = 210, and earth at the signal-box. In each case the resistance or electrical measurement of the circuits will be the coils of the instrument + R = 210, and the resistance of the coils being equal the current will be equally divided, and its influence equal. No magnetism will therefore be produced, and the armature will assume a normal position, producing the "caution" signal.

But now if the signal-arm is lowered to the "all clear" position, the line wire will be entirely disconnected at C, and thus there will be left but one road open for the current, viz., that *viâ* B′ and R 210. In this case the armature will be actuated in an opposite direction to that first explained, and the arm of the repeater will be lowered to the "all clear" position.

194. Another suggestion which has been made is that the various positions of the distant signal-arm shall bring into circuit a varying resistance, so that by the increased resistance thus thrown into the circuit the influence of the current over the armature of the instrument may be reduced until it reaches the zero point, which would, of course, be either the "all clear" or "danger" indication. It is scarcely a desirable arrangement; inasmuch as, for reasons which will be discussed hereafter, it is desirable the normal indication of a repeater instrument should be "all clear;" the opposite signal ("danger") would, under this arrangement, be dependent upon the force of the current. If this were from any cause reduced, the arm of the repeater would not rise to danger; the signalman would soon ascertain that this was from no fault of his

signal, and would, in the course of time, become indifferent to it, possibly, at a moment when his signal really did fail. In fact the indications, apart from the normal or zero position of the instrument, would not be those of the distant signal, but of the strength of the battery in relation to the resistance of the circuit.

195. The arm or the disc is the signal which governs the engine-driver by day, the light that which governs him by night. The methods by which a faithful record of the condition of the arm may be obtained have been fully dealt with, and thus the question of the day-signal may be said to have been disposed of.

The night-signal is dependent first on the light, and secondly on the "spectacles" or the colour of the light, viz., whether red or white, red or green, or whatever it may be.

The movement of the spectacles is, or should be, synchronous with that of the arm. They are usually attached to the rod which works the arm, and thus the motion which produces the danger-signal in the arm brings the red spectacle in front of the lamp, thereby showing a red light.

Hitherto but little, if any, attempt has been made to obtain a repetition of the movement of the spectacle. The need for such will be self-evident. The same causes which operate against a faithful action of the arm also operate against the spectacles, and it is equally as necessary that the night danger-signal should be as unmistakably a clearly defined red light, without any white showing, as that the day-signal should be a well defined horizontal position of the arm. Although improbable, there is yet the possibility of the framework of the spectacles becoming loose on the rod.

All that is necessary to obtain this record, is to make

the connection between the arm and the earth through the spectacles, so that when they occupy the danger position the circuit shall be complete, but when this position is in the least departed from the circuit shall be

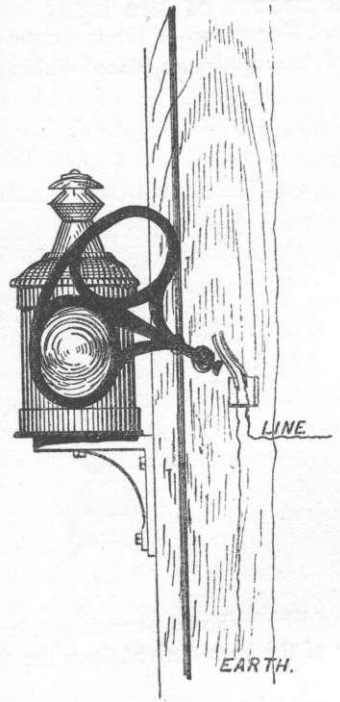

FIG. 105.

broken as represented in Fig. 105. Thus the movement of the arm and of the spectacles may, where the record required is that of the danger-signal only, be obtained by

one and the same wire. Where the various motions of the arm—danger, caution, and clear—are required, the connections at the spectacles must conform to those of the arm, the due action of the one being consequent upon that of the other.

196. **The record of the light** is obtained by a distinct wire. The action of the indicator depends upon the action of the apparatus placed within the lamp, the

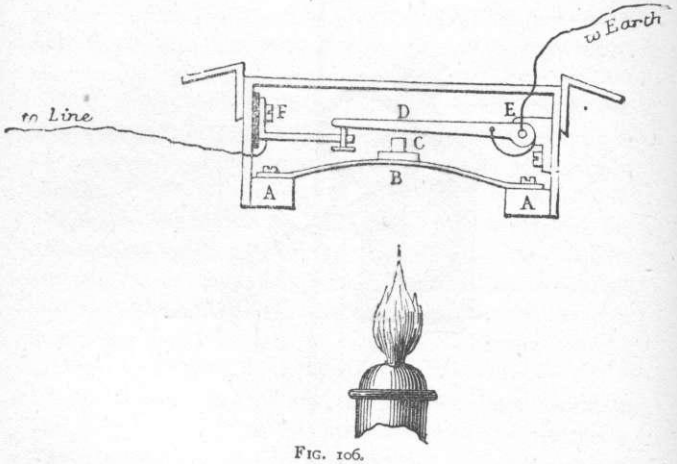

FIG. 106.

arrangement of which should be such that it will be under the influence of the heat derived from the flame furnishing the light.

Regarding Fig. 106 as a central cross-section of that portion of the apparatus employed within the lamp, A A is a circular iron frame, preferably made of cast-iron, as being less susceptible of expansion from heat. B is a disc of copper to fit A, beaten somewhat concave, and

firmly fixed at its circumference to the frame A. At its centre, on the reverse side to the frame, is a stud or pin C. D is an uninsulated lever centred at E, having imparted to it a tendency to move downwards by the spring at E. F is an insulated cock, with adjusting screw, the object of which is to regulate the space between C and D, as may be required, and to complete the electric circuit when D is in contact with it. To the insulated cock F the line-wire is joined, and the framework of the instrument is carried to earth. The diameter of the iron frame A may be about three inches, and the contact portion should be covered in to protect it from dirt. The whole may be very conveniently fitted within the top of a signal-lamp without interfering with the light or draught.

The internal arrangement of the "light" recording instrument consists of a pair of coils, to the armature of which is attached a wire rod with a bell-hammer at its extremity. Beneath the instrument is a bell-dome, so fixed that any movement of the armature shall cause it to be struck by the hammer. The line-wire is connected with the coils through a make-and-break arrangement, by which means, so long as a current flows through the wire, a continuous ringing of the bell is kept up. Between the poles of the electro-magnet is a permanent magnet carrying a shield with the words OUT and IN, so adjusted that it shall, under the influence of gravity, exhibit at an aperture in the face of the instrument the word IN, whilst the influence of the electric current shall, by reversing the position of the indicator, present the word OUT. Now if one pole of the battery be connected, through the make-and-break arrangement, to one end of the coil applying to the "light" instrument, and its other pole be put to earth, and the remaining end of the coil be connected

to the line-wire, we shall have, in the normal state of affairs—that is when there is no light in the lamp, —a continuous current flowing through the coils of the instrument along the line-wire to the adjusting screw F, and through the lever D, to earth at the signal-lamp. But now let a light be applied to the lamp. The heat will speedily expand the metal disc B, which in expanding will carry upwards the pin C, press it against the lever D, and finally carry away the latter from F. The line is then interrupted, and no current can pass: the bell ceases ringing, and the indicator being no longer under the influence of the current falls back to $\left\{\begin{matrix}\text{LIGHT}\\ \text{IN}\end{matrix}\right\}$, and there remains so long as the influence of the heat

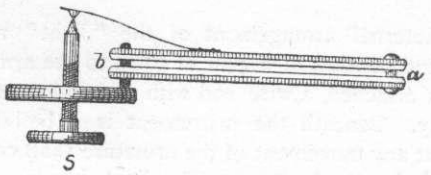

FIG. 107.

upon B keeps up its expansion. Thus, when the light is burning the indicator shows "light in," and the bell is quiet; when the light grows dim, or goes out, the electric circuit is again completed, the indicator records "light out," and the bell continues to ring until the light is restored. In front of the instrument is fixed a switch, for the purpose of putting the light arrangement in circuit at pleasure, as it is manifestly only required when the lamp is in use.

The "light" contact arrangement varies equally as much as does the form of indicator employed. Two dissimilar pieces of metal, as steel and brass, are at times

employed: or this may be duplicated as shown in Figs. 107, 107*a*.

The steel of the top-plate is on the upper side, the brass at the bottom. The lower plate has the steel underneath; they are both riveted together, at one end *a*, and at the other end *b*, *one* plate is connected with the side of the lamp. S is a contact-screw insulated from the rest of the apparatus.

Under the influence of heat the plates curve in opposite directions, and the lower composite plate also tips the top one upwards, adding this motion to that obtained by the curvature by heat, and the two plates assume something like the position shown by Fig. 107*a*.

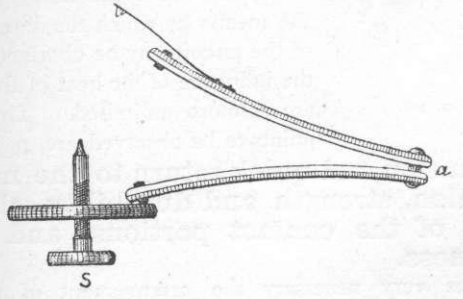

FIG. 107*a*.

Thus without the assistance of any multiplying lever or other device of the kind a very wide motion is obtained direct from the source, so affording great nicety of adjustment by the insulated contact-screw, as well as a good rubbing-contact.

Another simple method is that shown in Fig. 108.

A is a piece of $\frac{3}{4}$-inch brass tubing rigidly fixed at one end, B, to the iron frame G, provided with a brass pin at F, its other extremity, which is free to move within a slot.

D, cut in the frame. At S a small lever, SF, is centred at S, having its end, F, normally held in contact with the insulated cock C. The line-wire is connected to C, and the earth to the iron frame G.

On subjecting A to the influence of the heat of a flame of gas, or oil, or that of a candle, the tube will expand, and being immovable at B, this expansion will be in the direction of D. It will consequently press against that end of the lever SF, carry it away at F from the contact-stud C, and so break the electrical circuit.

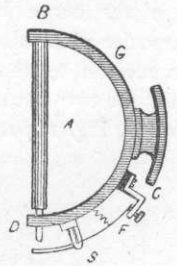

FIG. 108.

A spiral of metal has also been employed, but it will be evident that the means by which the interruption of the circuit may be obtained, under the influence of the heat of the flame, are almost unlimited. The main points to be observed are, **a ready expansion and quick return to the normal position, strength and durability, cleanliness of the contact portions, and compactness.**

It is very necessary the arrangement of the expansion-piece should be such as to insure its ready return, on the withdrawal of the heat under which it is made to expand, to its normal position, so as to insure contact between the line and the earth-wire. At the same time it should be strong and not too delicate, capable of good adjustment, and easily accessible to the lineman.

To adjust it for a ready intimation of any failure of the light, *the expansion-piece should be exposed to the heat of the flame for some twenty minutes, and then the adjusting screws in connection with the line-wire set so as to just break circuit.*

The main points to be considered in connection with the application of electric-repeaters are dealt with in the following remarks :—

197. *To what Signals should Repeaters be applied?*—It is scarcely necessary to say their chief application must be in connection with the distant signal. Distant signals are the farthest removed from the signalman, and are thus more apt to be obscured from his view in fogs and bad weather than those nearer home. At the same time it is an open question whether starting-signals and home-signals, and especially junction-signals erected over the signal-box, should not in a similar manner be repeated back to the signal-lever. It is no doubt a safe principle to consider the working of a railway under its most adverse circumstances, and to provide for it accordingly. Perhaps a dense fog is one of the worst conditions under which railway traffic can be worked. At such moments the importance of the due action of every signal cannot be over-estimated.

198. *The nature of the Indication.*—Considerable diversity of opinion exists as to the nature of the indication necessary to be recorded: whether the repeater should simply show when the signal is at "danger"; whether it should show when it is "on" and when it is "off"; or whether it should record the three positions, "danger," "caution," and "clear," or even go beyond this, and show the intermediate positions.

Now here let us consider what is the point of danger. Clearly the point of danger is that when a signal which is intended to be at danger, and which has, so far as the means of working it is concerned, been set at danger, *does not stand at danger.* It is then the man working it

requires to be told the signal is *not on*. If a signal does not stand *off* when it is supposed to have been pulled off, no positive danger will arise. An approaching train would draw on to within sight of the home-signal, and seeing this at "all clear" would proceed, the driver probably indicating to the signalman as he passed that his distant signal was not "off." With such indications and with the whistle of each succeeding train, the signalman would speedily see to the adjustment of the wire. Repeaters, to a considerable number, are worked on this principle; but one wire is required, and the battery power is only in operation during such time as the signal itself stands at *danger*.

To show when the signal is ON and OFF, or to show when it is at "danger," "caution," and "clear," requires two wires; an application of the duplex mode of working and a modified arrangement of the instrument; or placing the batteries at the signal-post, an objectionable course, as they would certainly freeze during very cold weather, and thus render the electrical-signal inoperative.

199. *The Point of Connection with the Signal.*—This is an important question. It is the arm which constitutes the signal by day and the "spectacles" by night. To these parts then the connection should be made. Hitherto no connection whatever has been attempted with the "spectacles," the attachment being made either to the arm, or to some part of the rod, or the lever working the rod in connection with the arm. A moment's reflection will show how desirable it is that the connection should be with both the arm and the spectacles in such a manner that the action of the one shall be made dependent upon the action of the other. This may be done by means of the same wire, and with merely the additional expense of another pair of springs.

It may be argued that there can be no reason to doubt the due action of the arm if the lever has *its* due action, but there *is* the chance, although perhaps a remote one, of a bolt giving way, or the arm becoming loose; and it is desirable to provide against such chances happening at inopportune moments. There are signals which, from their height and construction, it would be difficult to so fit, but these are the very signals which *should be so fitted*, because it may be fairly assumed they are, from those very causes, less likely to meet with that careful inspection from the mechanical branch of the service so necessary to keep them in proper repair, and so avoid failure.

Disc signals should in a like manner, where possible, be fitted at the iron shaft to which the disc is fitted, and the electrical connection with these should be made, as with the semaphore, through the fittings applied to the shaft carrying the lamp for the night signal.

200. *The Form of Instrument and its Indication.*—There is probably no great choice between the forms mentioned, for assuming every signalman is sufficiently educated to read the words inscribed he can make a mistake with difficulty; still there may be an advantage in employing that form of instrument which accords most with the signal, and requires merely a knowledge of the form and action of the signal to decipher a *danger* from a *clear* or *caution* signal.

201. *Electrical Construction.*—The instrument should be so constructed that it should be *undemagnetizable, and its signals unreversible from atmospheric causes.* Its normal condition should be that which affords the "all clear," or "caution" signal, where the signal repeated can only be lowered to that position. Its "danger" signal should be that produced by the action of the electric current.

The reasons for this will be self-evident. If the signal

be not unreversible from atmospheric causes there will be the possibility of the indication being opposite to that intended. If it is not undemagnetizable, the signal will be wanting in intensity or completeness. If its normal condition were that of *danger* instead of *all clear*, any defect in the apparatus, or the wire, would show the signal to be at danger when it might not be in that position. Constructed upon this principle, gravity may be employed to produce the *all clear* signal, and the action of the current the *danger* signal.

202. *Signalmen* should be instructed, wherever a repeater is in use, *not to suppose, if it should not act in concert with the signal-lever, that the repeater is wrong, but on the reverse, to conclude that it is his signal which is wrong, and to take steps at once to assure himself of the contrary.*

203. The electric repeater is a good disciplinarian. It introduces a *regularity* in the character of the signals which is otherwise frequently absent. Let the early traveller notice the signals at the different stations as he passes along. Here he will see one standing well out, fully at danger; there another with an inclination towards caution, ashamed, as it were, to look the driver in the face. The manner in which a signal is made to deliver its message is a very good indication of the character of the man who works it. If it comes well to danger, and again falls well to clear or caution, it is well attended, and shows a desire on the part of the man who works it to carry out his duties well and faithfully. A slovenly man is too lazy to attend to the adjustment of his wire until he is obliged to do so; but let him have before him a monitor which says to him, "Your signal is not on," when he has contented himself with throwing his lever over to danger, and his responsibility is too great for him to disregard it.